PB-230 022

STREAM POLLUTION BY COAL MINE DRAINAGE IN APPLACHIA

Federal Water Pollution Control
Administration
Cincinnati, Ohio

1969

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

PB 230 022

REGION III LIBRARY
ENVIRONMENTAL PROTECTION AGENCY

STREAM POLLUTION BY COAL MINE DRAINAGE IN APPALACHIA

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
CINCINNATI, OHIO

PREPARED 1967 and
REVISED 1969

260

FOREWORD

This publication constitutes a status report of Federal Water Pollution Control Administration studies concerning the sources and extent of coal mine drainage stream pollution in the Appalachian Region and is intended to serve as a summary reference regarding those aspects of the problem.

The documentation of streams affected by coal mine drainage is essentially complete. It is based on extensive field studies done by FWPCA supplemented by information obtained from the States in the Region. Preliminary inventories of coal mine drainage sources have been completed in watersheds wherein 75 percent of the acid drainage in Appalachia originates. Inventory work in the Allegheny River basin was done cooperatively with the State of Pennsylvania. In all areas, more refined stream and source inventory studies will be required as abatement work progresses in order to allow design of specific abatement programs in the individual watersheds.

The information in this report was obtained primarily from continuing FWPCA projects. However, special effort was made to time preparation of the report so that it could be included as part of the "Development of Water Resources in Appalachia," a water resource survey authorized in Section 206 of the Appalachian Regional Development Act of 1965. During 1968 and 1969, it became apparent that information in "Stream Pollution by Coal Mine Drainage in Appalachia" would also constitute a significant contribution to the Appalachian Regional Commission study of acid mine drainage in Appalachia as authorized by the Appalachian Regional Development Act Amendments of 1967. It was, therefore, agreed that "Stream Pollution by Coal Mine Drainage" would also appear as part of an appendix to the Appalachian Regional Commission's 1969 report, "Acid Mine Drainage in Appalachia."

The cooperation of the States and other Federal agencies that provided information contained herein or assistance is appreciatively acknowledged. In particular, I wish to acknowledge the cooperation of the U.S. Army Corps of Engineers Office of Appalachian Studies in providing assistance in the drafting and printing of the report.

Richard A. Vanderhoof, Regional Director
Ohio Basin Region
Federal Water Pollution Control Admin.
and
Coordinator of Appalachian Activities
for FWPCA

Preceding page blank

TABLE OF CONTENTS

	Page
Foreword	iii
Introduction	1
General statement	1
Purpose and scope	1
Summary and conclusions	3
Sources of coal mine drainage pollution	11
Formation of pollutants in mine drainage	13
Water quality evaluation	15
Damages	18
Water supplies	18
Recreation	19
Present conditions	20
Methods of study	20
Sub-area discussions	22
Anthracite area	22
Description	22
Mine drainage sources and their effect on stream quality	24
Tioga River basin	59
Description	59
Mine drainage sources and their effect on stream quality	59
West Branch Susquehanna River basin	67
Description	67
Mine drainage sources and their effect on stream quality	68

TABLE OF CONTENTS (cont'd)

Page

Juniata River basin 87
  Description 87
  Mine drainage sources and their effect on stream quality 88

North Branch Potomac River basin 95
  Description 95
  Mine drainage sources and their effect on stream quality 96

Allegheny River basin 107
  Description 107
  Mine drainage sources and their effect on stream quality 108

Monongahela River basin 127
  Description 127
  Mine drainage sources and their effect on stream quality 128

Beaver River basin 143
  Description 143
  Mine drainage sources and their effect on stream quality 143

Muskingum River basin 149
  Description 149
  Mine drainage sources and their effect on stream quality 149

Hocking River basin 157
  Description 157
  Mine drainage sources and their effect on stream quality 157

Little Kanawha River basin 165
  Description 165
  Mine drainage sources and their effect on stream quality 165

Kanawha River basin 169
  Description 169
  Mine drainage sources and their effect on stream quality 170

TABLE OF CONTENTS (cont'd)

	Page
Scioto River basin	174
Description	174
Mine drainage sources and their effect on stream quality	174
Guyandotte River basin	177
Description	177
Mine drainage sources and their effect on stream quality	177
Big Sandy River basin	185
Description	185
Mine drainage sources and their effect on stream quality	185
Ohio River Main Stem and minor tributaries	195
Description	195
Mine drainage sources and their effect on stream quality	195
Kentucky River basin	209
Description	209
Mine drainage sources and their effect on stream quality	209
Cumberland River basin	221
Description	221
Mine drainage sources and their effect on stream quality	222
Tennessee River and Black Warrior River basins	239
Description	239
Mine drainage sources and their effect on stream quality	239
Projected Conditions	253
References	258

LIST OF FIGURES (cont'd)

No. Page

1 Index map of Appalachia 9
2 Map of Anthracite area 37
3 Sulfate loads, Lehigh River 39
4 Sulfate loads, Schuylkill River 40
5 Sulfate loads, Susquehanna River 41
6 Flow and alkalinity profiles, Lackawanna River 42
7 Water quality profiles, Lackawanna River 43
8 Flow and alkalinity profiles, Susquehanna River 44
9 Water quality profiles, Susquehanna River 45
10 Flow and alkalinity profiles, Catawissa Creek 46
11 Water quality profiles, Catawissa Creek 47
12 Flow and alkalinity profiles, Shamokin Creek 48
13 Water quality profiles, Shamokin Creek 49
14 Flow and alkalinity profiles, Mahanoy Creek 50
15 Water quality profiles, Mahanoy Creek 51
16 Flow and alkalinity profiles, Mahantango Creek 52
17 Water quality profiles, Mahantango Creek 53
18 Flow and alkalinity profiles, Wiconisco Creek 54
19 Water quality profiles, Wiconisco Creek 55
20 Flow and alkalinity profiles, Swatara Creek 56
21 Water quality profiles, Swatara Creek 57
22 Map of Tioga River basin 63
23 Flow and alkalinity profiles, Tioga River 65
24 Water quality profiles, Tioga River 66
25 Map of West Branch Susquehanna basin 81
26 Sulfate loads, West Branch Susquehanna River 83
27 Flow and alkalinity profiles, West Branch Susquehanna River 84
28 Water quality profiles, West Branch Susquehanna River 85
29 Schematic diagram, Clearfield Creek 73
30 Schematic diagram, Moshannon Creek 75
31 Map of Juniata River basin 91
32 Flow and alkalinity profiles, Raystown branch Juniata River 93
33 Water quality profiles, Raystown branch Juniata River 94
34 Map of North Branch Potomac River basin 103
35 Flow and alkalinity profiles, North Branch Potomac River 105
36 Water quality profiles, North Branch Potomac River 106
37 Map of Allegheny River basin 123
38 Sulfate loadings, Allegheny River 125
39 Sulfate loadings, Kiskiminetas River 126
40 Map of Monongahela basin 139
41 Sulfate loads, Monongahela River 141
42 Sulfate loads, Youghiogheny River 142
43 Map of Beaver River basin 147
44 Map of Muskingum River basin 155

LIST OF FIGURES (cont'd)

No.		Page
45	Map of Hocking River basin	161
46	Sulfate loads, Hocking River	163
47	Map of Little Kanawha basin	167
48	Map of Kanawha River basin	173
49	Map of Scioto River basin	175
50	Map of Guyandotte River basin	183
51	Map of Big Sandy River basin	191
52	Sulfate loads, Big Sandy River	193
53	Map of Ohio River, Pittsburgh to New Cumberland	203
54	Map of Ohio River, New Cumberland to Bellville Dam	205
55	Map of Ohio River,	207
56	Map of Kentucky River basin	219
57	Map of Cumberland River basin	235
58	Sulfate loads, Cumberland River	237
59	Map of a portion of Tennessee River basin, Virginia	245
60	Map of a portion of Tennessee River basin, Tennessee	247
61	Map of a portion of Tennessee River basin, Tennessee, Georgia, and Alabama	249
62	Map of a portion of Black Warrior River basin, Alabama	251

LIST OF TABLES

No.		Page
1	Summary of Appalachia mine drainage data	5
1A	Coal mine drainage sources in Appalachia	6
1B	Statistical distribution of mine drainage source categories	8
2	Water quality criteria	16a
3	Principal drainages contributing acidity to Clearfield Creek	72
4	Principal drainages contributing acidity to Moshannon Creek	76
5	Lengths of streams polluted by mine drainage, Allegheny basin	108
6	Acidity loads in Allegheny basin streams	111
7	Water quality data, Allegheny basin	115
8	Lengths of streams polluted by mine drainage Monongahela basin	129
9	Acidity loads in Monongahela basin streams	130
10	Water quality data, Monongahela basin	133
11	Water quality data, Beaver basin	144
12	Lengths of mine drainage polluted streams, Muskingum basin	150
13	Water quality data, Muskingum basin	152
14	Water quality data, Hocking basin	159
15	Lengths of mine drainage polluted streams, Kanawha basin	170
16	Water quality data, Kanawha basin	172
17	Water quality data, Guyandotte basin	181
18	Lengths of mine drainage polluted streams, Big Sandy basin	186
19	Water quality data Big Sandy basin	188
20	Lengths of mine drainage polluted streams Ohio Main Stem tributaries	196
21	Water quality data, Ohio Main Stem tributaries	199
22	Mine drainage polluted streams, Kentucky basin	210
23	Water quality data, Kentucky basin	213
24	Mine drainage polluted streams, Appalachian portion Cumberland basin	222
25	Water quality data, Cumberland basin	226
26	Mine drainage polluted streams, Appalachian portion Tennessee basin	240
27	Water quality data, Tennessee basin	243
28	Listing of streams for which average yearly sulfate loads are given	253

INTRODUCTION

General Statement

Coal is the most abundant mineral resource in Appalachia and 75 percent of the total cumulative coal production in the United States has been from this area. Coal deposits underlie more than 72,000 square miles of Appalachia, about 40 percent of the total area.

Some discoloration of streams by the natural drainage from hillsides containing coal deposits was observed to exist by Gabriel Thomas in 1698 (Eavenson, 1942). After the advent of commercial mining, coal mine drainage stream pollution began to have serious effects, and as early as 1890, the Youghiogheny River at McKeesport, Pennsylvania, contained sufficient pollutants from coal mining activities to kill fish at times (U.S. Public Health Service, 1962). Today, pollution of streams in Appalachia by coal mine drainage may qualify as the single most significant pollution problem in terms of the severity of damage to streams and in terms of the effort that will be required in abating this pollution.

Coal mine drainage pollution as it is generally conceived of begins with the exposure of iron sulfide minerals associated with coal to the atmosphere during mining. The exposed relatively insoluble sulfide minerals are converted by oxidation to soluble sulfuric acid and to iron compounds. The sulfuric acid may in turn dissolve other minerals such as manganese, aluminum, and calcium.

The sulfuric acid, iron, and other minerals in mine drainage affect water use in various ways. To many, the most dramatic effects of mine drainage pollution are in the destruction of fish and other aquatic life and impairment to stream appearance that often occur. Mine drainage pollution may affect the use of water for municipal and industrial water supply by increasing the costs for equipment and for water treatment. Additional damaging effects of mine drainage are to increase the corrosiveness of the polluted water to boats and to dams and other structures built in the polluted streams.

Purpose and Scope

This report is intended to serve as a summary reference concerning the occurrence and sources of coal mine drainage pollution in Appalachia.

The general distribution of coal mine drainage pollution in Appalachia has long been known, but recent data were not available to show, in detail, the streams affected and their quality. Therefore, documentation of the extent of the problem constitutes the major part of the report. In some areas all available stream water quality data are presented; in other areas only representative data are included. In all areas, additional stream water quality and streamflow data will be required as abatement work progresses. A preliminary effort has been made to locate and describe coal mine pollution sources in those watersheds that contribute 75 percent of the acid entering Appalachian streams. This effort is sufficient to establish the relative numbers and types of sources in the various watersheds and their individual pollution contributions at the time of investigation, but much more detailed study of the individual sources will be needed to allow design of a specific abatement program in any individual watershed. Pollution sources are described here in only a broad statistical way. Descriptions of the amount and chemical quality of individual discharges and the type of mine or other source are in the files of FWPCA and State agencies and, in some cases, in more detailed reports that cover sub-areas of Appalachia.

Designs and cost estimates for specific mine drainage abatement projects are not discussed here. Such designs and cost estimates as have been prepared are primarily for watersheds in Pennsylvania, where $150 million has been allocated for the abatement of pollution from abandoned mines. Some mine drainage pollution abatement projects that have been recommended as emergency or top priority projects in Pennsylvania are discussed in the Pennsylvania State Water Resources Supplement to the Development of Water Resources in Appalachia. Other sources of information concerning the development of abatement projects in Appalachia are the monthly Secretary's Report of the Department of Mines and Mineral Industries and Pennsylvania's Ten Year Mine Drainage Pollution Abatement Program for Abandoned Mines, which is published by the Pennsylvania Sanitary Water Board, Department of Health.

SUMMARY AND CONCLUSIONS

Data that characterize the present problem of stream pollution by coal mine drainage in Appalachia are presented in Tables 1, 1-A, and 1-B. The sub-areas of Appalachia that are listed in Table 1 are shown in Figure 1.

Table 1 lists the sub-areas discussed in the report and presents data pertinent to coal mine drainage pollution. Table 1 shows that 10,500 miles of Appalachian streams are significantly affected by coal mine drainage pollution, 6,700 miles of these on a continuous basis. Approximately 68 percent of the mine drainage acidity formed in Appalachia originates in the Monongahela, Allegheny, and Susquehanna-Delaware River basins of Pennsylvania, West Virginia, and Maryland. Forty-three percent of the affected miles of streams are in these watersheds. Significant amounts of acid drainage and consequent polluted streams occur in the Beaver, Muskingum, Hocking, Kanawha, and Big Sandy River basins and in smaller streams that are directly tributary to the Ohio River between Pittsburgh and Cincinnati. Lesser amounts of pollution exist in the other watershed areas listed, but the effects may still be significant locally.

Coal mine drainage pollutants affect water quality by lowering the pH, reducing the natural alkalinity, increasing the total hardness, and by adding undesirable amounts of iron, manganese, aluminum, sulfates, and other chemicals. Sediment is eroded from mined areas and fine coal enters streams from coal processing plants and refuse disposal areas.

Adverse effects to municipal and industrial water use are caused by the chemicals, silt, fine coal, and added color that result from coal mining and coal processing. Corrosion of boats, bridges, locks and dams, and other facilities and equipment is accelerated by acid mine drainage. Discharge of mine drainage and coal mining or coal processing wastes into streams and lakes impairs their quality for fishing and makes them unattractive for boating, water skiing and swimming, and lowers their value as a scenic resource.

The distribution of mine drainage pollution throughout Appalachia is a result of numerous factors including topography, geology, hydrology, amount of pyritic minerals present, and mining methods used. However, the present distribution of pollution is primarily a result of the amount of pyritic minerals present and the extent of mining. Intensively polluted areas are ones where mining has been extensive and where pyritic minerals are relatively abundant.

Table 1-A summarizes data for 5,570 significant sources of mine drainage pollution that have been located and described in Appalachia during 1964-1968 by FWPCA, in many instances in cooperation with the State of Pennsylvania. The watersheds that have been surveyed contribute about three quarters of the 6,000 tons/day of acid that enters Appalachian streams. However, the total amount of acid measured at the 5,570 individual sources only amounts to about 1,600 tons/day, approximately one-quarter of the 6,000 tons/day of acid estimated to enter Appalachian streams. This large discrepancy results because source inventories were conducted primarily during the dry summer months and because there are undoubtedly many additional sources that were not located during the initial surveys that were performed.

Of the sources that have been inventoried, inactive underground mines contribute 52 percent of the acid, active underground mines 19 percent, inactive surface mines 11 percent and active surface mines 1 percent (Table 1-B). Most of the remaining sources are in combination surface-underground mines. Refuse piles and coal processing plants contribute about 7 percent of the total acid measured. Inactive sources contribute 78 percent of the acid and active sources 22 percent. A significant fact, not brought out in Tables 1-A and 1-B, is that frequently a major amount of the pollution in a particular watershed is contributed by a few sources, and that the degree of success in controlling drainage from these few sources will determine the success of an abatement program. It is apparent that the success of any large-scale mine drainage pollution abatement program will depend on the ability to control drainage pollution originating in abandoned underground mines.

Examination of the available historical stream quality data indicates that while fluctuations have occurred in mine drainage pollution loads, substantial permanent increases in acid loads do not appear to have occurred within the past 20 to 25 years. These data indicate that total pollution loads in large sub-areas of Appalachia, such as are listed in Table 1, will tend to remain in the same order of magnitude within the next few decades unless corrective measures are applied.

Although the total quantity of pollutants discharged to Appalachian streams may not be tending to increase rapidly, it is expected that the mine drainage pollution problem will become more severe in terms of the number of inactive mines contributing pollution. In addition, previously unpolluted streams will be degraded as mining advances into new areas unless effective controls are established over the opening and abandment of new mines. The potential for further pollution from mining activities is reflected by the fact that remaining recoverable reserves of bituminous coal in Appalachia are equal to 440 times the 1964 production and seven times the total cumulative production from the beginning of mining to 1965 (Arndt and others, 1968).

Table 1 - Summary of Data Concerning Mine Drainage Pollution in Appalachia

Subarea in Appalachia	Drainage Area in Appalachia (square miles)	Mine Drainage Acidity Formed in Basin (tons/day)	Acidity Discharged to Streams - 1966 (tons/day)	Miles of Polluted Streams Inter-mittently	Miles of Polluted Streams Continu-ously	Miles of Polluted Streams Total
Anthracite Region (Susquehanna & Delaware)	4,200	2,300	350	350	260	610
Tioga	2,800	10	8	20	35	55
West Branch Susquehanna	6,900	700	250	600	540	1,140
Juniata	3,400	60	19	20	60	80
North Branch Potomac	2,200	70	33	40	130	170
Allegheny	11,730	2,400	1,600	87	979	1,066
Monongahela	7,400	3,000	1,200	289	1,382	1,671
Beaver	1,500	> 165	50	40	68	108
Muskingum	4,340	500	400	108	414	522
Hocking	1,200	335	200	141	223	364
Little Kanawha	2,300	> 10	10	25	5	30
Kanawha	12,300	550	350	544	859	1,403
Scioto	2,300	10	5	8	0	8
Guyandotte	1,670	200	100	11	288	299
Big Sandy	4,300	620	300	442	58	500
Ohio & Minor Tributaries	12,600	> 1,000	1,000	166	1,164	1,330
Kentucky	4,500	> 155	> 100	430	65	495
Cumberland	10,850	> 200	> 200	305	205	510
Tennessee - Black Warrior	28,000	> 20	> 20	--	--	155
		> 12,305	> 6,195	3,656	6,705	10,516

1/ From U. S. Geological Survey Prof. Paper 580, Mineral Resources of the Appalachian Region.

Table 1 - Summary of Data Concerning Mine Drainage Pollution in Appalachia

rainage y Formed in /day)	Acidity Discharged to Streams - 1966 (tons/day)	Miles of Polluted Streams Inter-mittently	Continu-ously	Total	Unreclaimed Surface Mined Lands (acres)	Area Underlain by Coal Reserves (square miles)	Recoverable Coal (millions of tons)
00	350	350	260	610	84,200	489	1,600
10	8	20	35	55	4,000	59	17
00	250	600	540	1,140	71,300	3,606	2,126
0	19	20	60	80	20,400	81	95
70	33	40	130	170	5,000	720	—
00	1,600	87	979	1,066	79,000	6,700	11,000
00	1,200	289	1,382	1,671	79,000	5,500	23,000
5	50	40	68	108	20,000	1,120	3,000
00	400	108	414	522	29,000	3,580	8,000
5	200	141	223	364	4,000	1,000	> 1,000
10	10	25	5	30	4,000	1,400	2,000
0	350	544	859	1,403	64,000	8,600	23,000
0	5	8	0	8	1,000	350	150
0	100	11	288	299	11,000	1,600	5,000
0	300	442	58	500	31,000	4,300	11,000
0	1,000	166	1,164	1,330	48,000	9,400	--
5	> 100	430	65	495	10,000	3,000	--
0	> 200	305	205	510	29,000	7,500	--
0	> 20	--	--	155	18,600		—
5	> 6,195	3,656	6,705	10,516	613,500		156,608[1]

---

[1] Mineral Resources of the Appalachian Region.

B

Table 1-A

Coal Mine Drainage Sources Inventor
by FWPCA in Appalachia - March 196

Sub-area	Active Operations							
	Underground Mines		Surface Mines		Combination Surface & Underground Mines		Other Sources[1]	
	No. of Sources	Net Acidity (lbs./day)	No. of Sources	Net Acidity (lbs./day)	No. of Sources	Net Acidity (lbs./day)	No. of Sources	Net Acidity (lbs./day)
Anthracite Area								
Susquehanna Basin	36	127,200	-	-	-	-	-	-
Delaware Basin	4	2,800	-	-	-	-	-	-
Tioga River	-	-	-	-	-	-	-	-
West Branch Susquehanna	19	12,800	17	2,500	-	-	-	-
Juniata River	-	-	-	-	-	-	-	-
Allegheny River								
Clarion River	4	130	3	1,281	1	324	1	60
Kiskiminetas River	31	145,986	5	508	-	-	1	84
Monongahela River	175	325,494	49	24,007	23	60,288	23	5,877
Ohio River Tributaries								
Wheeling Cr.	2	137	-	-	-	-	-	-
Raccoon Cr.	-	-	1	84	-	-	1	869
Captina Cr.	7	346	-	-	-	-	2	6,371
Total Sources Inventoried	278	614,201	75	28,380	24	60,612	28	13,261

[1] Other active sources are coal processing plants and refuse disposal areas associated with active mines.

[2] Other inactive sources are abandoned refuse piles and seepages that can not be identified with specific so

Table 1-A

Mine Drainage Sources Inventoried
FWPCA in Appalachia - March 1969

		Inactive Operations							
Other Sources 1/		Underground Mines		Surface Mines		Combination Surface & Underground Mines		Other Sources 2/	
No. of Sources	Net Acidity (lbs./day)	No. of Sources	Net Acidity (lbs./day)	No. of Sources	Net Acidity (lbs./day)	No. of Sources	Net Acidity (lbs./day)	No. of Sources	Net Acidity (lbs./day)
-	-	73	387,400	3	900	-	-	1	100
-	-	41	25,300	3	300	-	-	-	-
-	-	15	21,700	7	2,400	-	-	-	-
-	-	560	266,600	267	104,600	-	-	104	112,500
-	-	44	37,900	-	-	-	-	-	-
1	60	145	33,180	240	92,643	57	18,786	40	7,099
1	84	381	423,945	155	13,223	107	26,089	84	102,358
23	5,877	1,619	452,739	749	116,206	249	111,285	8	8,994
-	-	41	5,333	12	771	16	7,590	1	131
1	869	31	57,229	69	30,118	39	74,145	1	63
2	6,371	3	134	-	-	-	-	-	-
28	13,261	2,953	1,711,460	1,505	361,161	468	237,895	239	231,145

ssociated with active mines.

be identified with specific sources.

B

Table 1-A

Coal Mine Drainage Sources Inventoried by FWPCA in Appalachia - March 1969 (Cont.)

Sub-area	Source Category Totals									
	Active Sources		Inactive Sources		Underground Sources		Surface Sources		Combina Sourc	
	No. of Sources	Net Acidity (lbs./day)	No. of Sources	Net Acidity (lbs./day)	No. of Sources	Net Acidity (lbs./day)	No. of Sources	Net Acidity (lbs./day)	No. of Sources	A (lb
Anthracite Area										
Susquehanna Basin	36	127,200	77	388,400	109	514,600	3	900	-	
Delaware Basin	4	2,800	44	25,600	45	28,100	3	300	-	
Tioga River	-	-	22	24,100	15	21,700	7	2,400	-	
West Branch Susquehanna	36	15,300	931	483,700	579	279,400	284	107,100	-	
Juniata River	-	-	44	37,900	44	37,900	-	-	-	
Allegheny River										
Clarion River	9	1,795	482	151,708	149	33,310	243	93,924	58	1
Kiskiminetas River	37	146,578	727	565,615	412	569,931	160	13,731	107	2
Monongahela River	270	415,666	2,625	689,224	1,794	778,233	798	140,213	272	17
Ohio River Tributaries										
Wheeling Cr.	2	137	70	13,825	43	5,470	12	771	16	7
Raccoon Cr.	2	953	140	161,555	31	57,229	70	30,202	39	7
Capatina Cr.	9	6,025	3	134	10	212	-	-	-	
Total Sources Inventoried	405	716,454	5,165	2,541,761	3,231	2,325,661	1,580	389,541	492	29

Table 1-A

Coal Mine Drainage Sources Inventoried by FWPCA in Appalachia - March 1969
(Cont.)

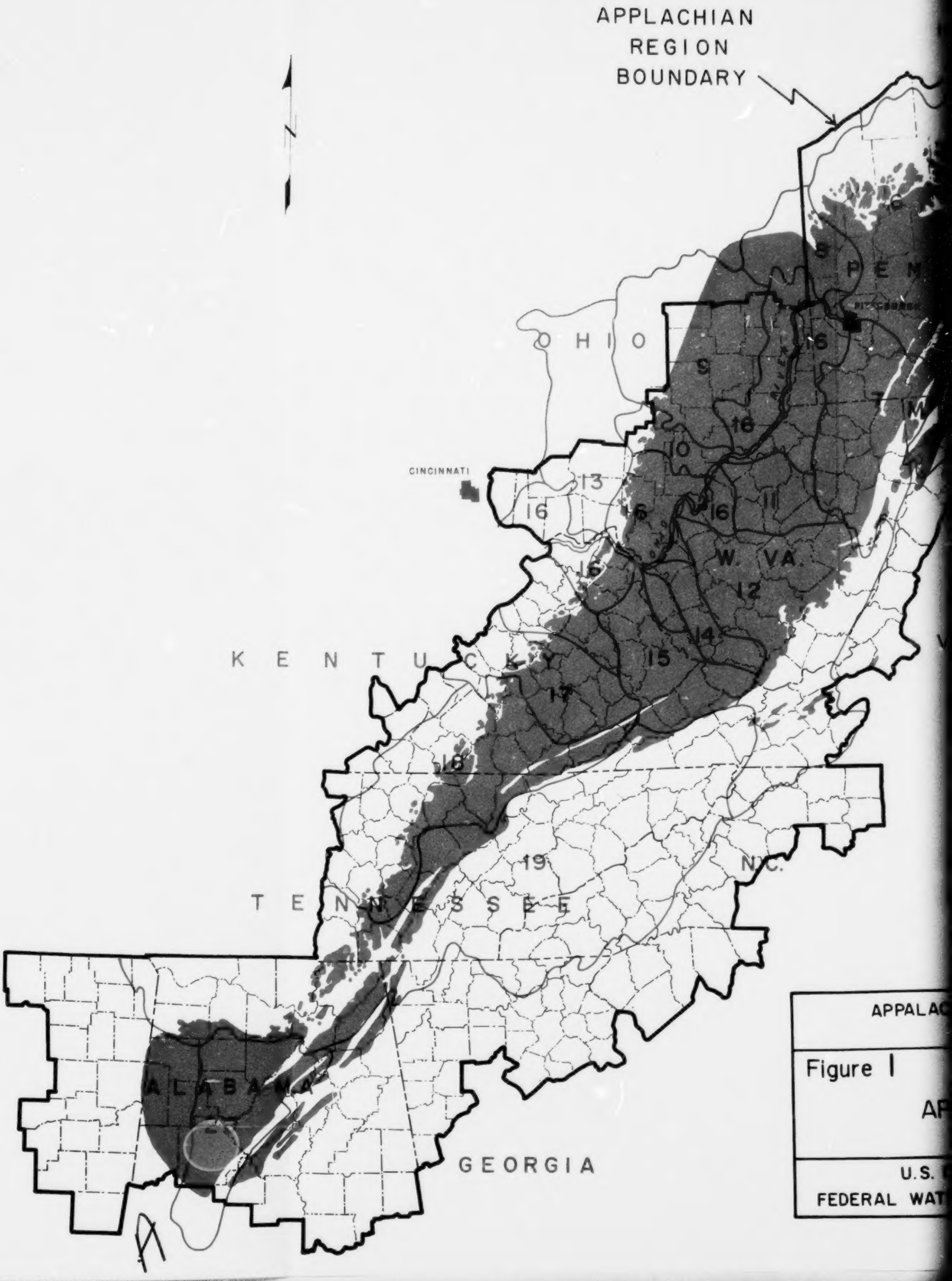
Source Category Totals									
Underground Sources		Surface Sources		Combination Sources		Other Sources		Total Sources	
No. of Sources	Net Acidity (lbs./day)	No. of Sources	Net Acidity (lbs./day)	No. of Sources	Net Acidity (lbs./day)	No. of Sources	Net Acidity (lbs./day)	No. of Sources	Net Acidity (lbs./day)
109	514,600	3	900	-	-	1	100	113	515,600
45	28,100	3	300	-	-	-	-	48	28,400
15	21,700	7	2,400	-	-	-	-	22	24,100
579	279,400	284	107,100	-	-	104	112,500	967	499,000
44	37,900	-	-	-	-	-	-	44	37,900
149	33,310	243	93,924	58	19,110	41	7,159	491	153,503
412	569,931	160	13,731	107	26,089	85	102,442	764	712,193
1,794	778,233	798	140,213	272	171,573	31	14,871	2,895	1,104,890
43	5,470	12	771	16	7,590	1	131	72	13,962
31	57,229	70	30,202	39	74,145	2	932	142	162,508
10	212	-	-	-	-	2	6,371	12	6,159
3,231	2,325,661	1,580	389,541	492	298,507	267	244,506	5,570	3,258,215

B

Table 1-B

Statistical Distribution by Number and Acid Contribution of Mine Drainage Source Categories Shown in Table 1-A

	Source Category				
Percent of Total Sources	Underground Mines	Surface Mines	Combination Surface & Underground Mines	Other Sources	Total Percentages
Active Sources	5.0	1.4	0.4	0.5	7.3
Inactive Sources	53.0	27.0	8.4	4.3	92.7
Total	58.0	28.4	8.8	4.8	100.0
Percent of Net Acidity					
Active Sources	18.8	0.9	1.9	0.4	22.0
Inactive Sources	52.5	11.1	7.3	7.1	78.0
Total	71.3	12.0	9.2	7.5	100.0


APPLACHIAN
REGION
BOUNDARY
OHIO
PEN
PITTSBURGH
CINCINNATI
KENTUCKY
W. VA.
TENNESSEE
N.C.
ALABAMA
GEORGIA
6
8
9
10
11
12
13
14
15
16
17
18
19

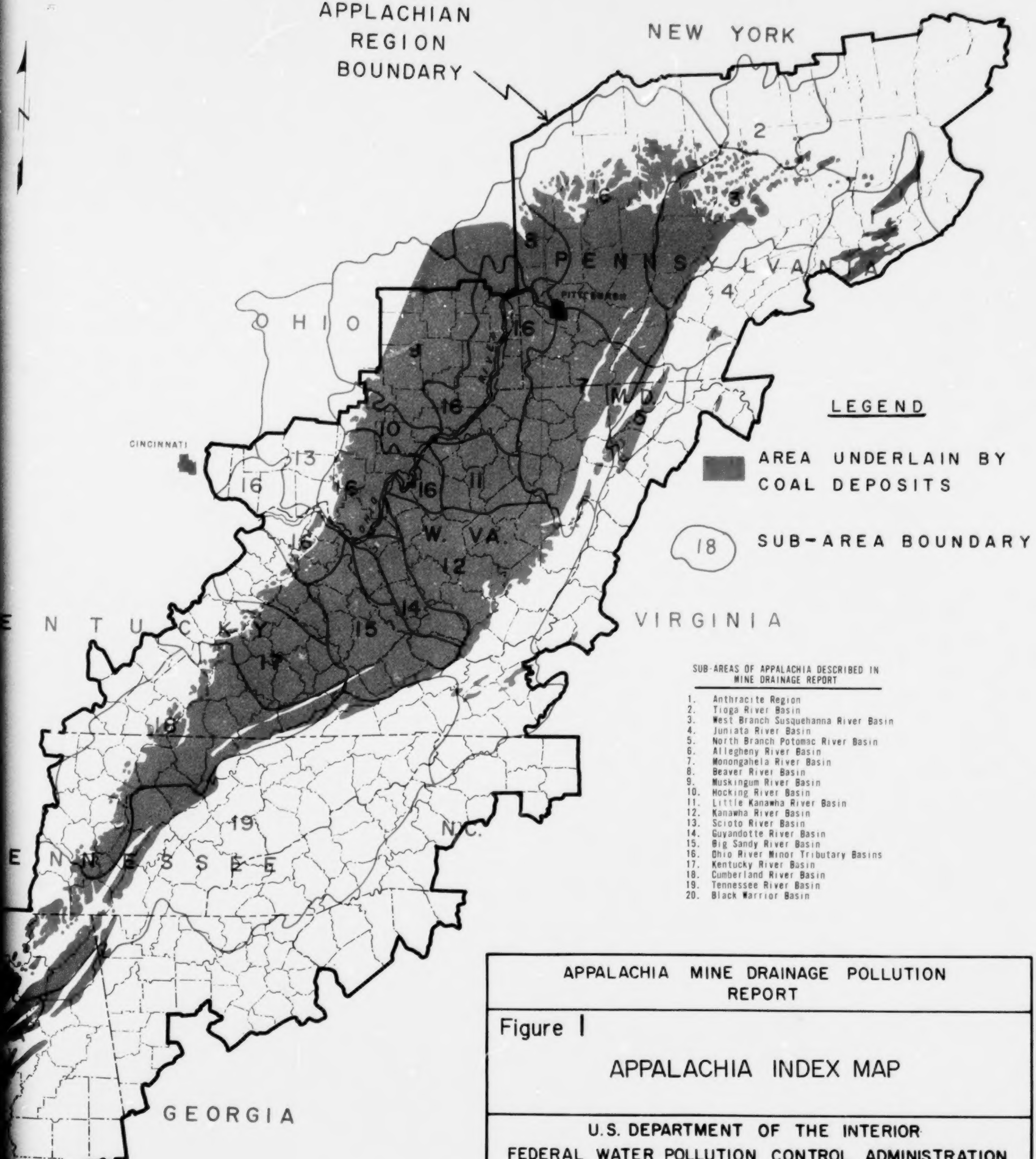
APPALAC

Figure 1

AP

U.S.
FEDERAL WAT

A


APPLACHIAN
REGION
BOUNDARY
NEW YORK
PENNSYLVANIA
PITTSBURGH
OHIO
MD.
W. VA.
VIRGINIA
KENTUCKY
TENNESSEE
N.C.
GEORGIA
CINCINNATI
OHIO RIVER
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
LEGEND
AREA UNDERLAIN BY COAL DEPOSITS
18
SUB-AREA BOUNDARY

SUB-AREAS OF APPALACHIA DESCRIBED IN MINE DRAINAGE REPORT

1. Anthracite Region
2. Tioga River Basin
3. West Branch Susquehanna River Basin
4. Juniata River Basin
5. North Branch Potomac River Basin
6. Allegheny River Basin
7. Monongahela River Basin
8. Beaver River Basin
9. Muskingum River Basin
10. Hocking River Basin
11. Little Kanawha River Basin
12. Kanawha River Basin
13. Scioto River Basin
14. Guyandotte River Basin
15. Big Sandy River Basin
16. Ohio River Minor Tributary Basins
17. Kentucky River Basin
18. Cumberland River Basin
19. Tennessee River Basin
20. Black Warrior Basin

APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 1

APPALACHIA INDEX MAP

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

SOURCES OF COAL MINE DRAINAGE POLLUTION

Several methods are presently used to recover coal; however, all the methods fall within the two general types of either surface or underground operations.

Surface, or strip mining, is practical in areas where the rock and soil overburden is relatively thin. The thickness of overburden for economical removal depends not only on the coal reserves but also upon the type of machinery that can be utilized. In selected areas, more than 100 feet of overburden rock have been stripped by means of large power shovels or other machinery. The first large strip trench that is formed is utilized for depositing the overburden from the adjacent trench. Consequently, in areas where the coal is relatively flat lying and the land surface is also of relatively low relief, strip mining disturbs large areas or blocks of land.

Where the coal crops out in a hill, the overburden thickens quickly and surface mining is limited to stripping of the coal outcrop around the hill. In order to remove additional coal from inside the hill, auger mining is commonly used after the final strip cut. Large augers, some of which are as much as seven feet in diameter, can mine several hundred additional feet into the hill.

In places where the overlying rock materials are thick, underground mining must be employed. Where the coal crops out at the land surface, a drift mine entry is constructed and mining is advanced into the coal bed. Where the coal bed is buried a considerable distance beneath the overlying rocks, a vertical shaft or a slope mine entry is constructed to the coal. Lateral entries are then driven into the coal bed.

All methods of surface and underground mining may result in some degree of mine drainage pollution. The quality and quantity of mine drainage pollutants produced from a mining operation depends upon such factors as:

(1) The operating status of the mine (i.e., active or inactive).
(2) Hydrologic, geologic, and topographic features of the surrounding terrain.
(3) The type of mining method employed.
(4) Availability of air, water, and iron sulfide minerals.

Drainage from a mining operation may be produced continuously or intermittently. Underground mines developed below the ground water table usually produce mine drainage continuously, the concentration of

Preceding page blank

pollutants varying as a function of the volume of water entering the mine, contact time, and available reactive materials. In cases where the ground water table is below the mining level during some seasons or when the mine receives direct surface water contributions, the discharge quality and quantity may vary greatly.

In surface mines, the discharge of the pollutants is often intermittent, generally occurring during and immediately after periods of precipitation. Runoff in stripped areas may find its way to a surface stream or be trapped in inadequately restored trenches or pits formed during the stripping operation. When the runoff is trapped, pools which may contain high concentrations of mine drainage pollutants are formed. During subsequent periods of high runoff, these pools may overflow, releasing concentrated "slugs" of mine drainage pollution to receiving streams. Although streams that are only intermittently polluted may be of good quality much of the time, the aquatic life community of streams receiving "slugs" of acid mine drainage may be damaged for extensive periods of time.

Between flush out periods, the pools in stripped areas often drain slowly into the backfill to emerge in the form of mine drainage seepages downslope from the stripping operation. They may also drain to underground mines underlying the stripped area, thus increasing the mine drainage flow from these mines. Mine drainage may continue to flow from inactive surface and underground mines as long as air, water, and sulfide minerals are available.

Disposal of the refuse materials from mines and coal preparation plants is one of the most difficult problems associated with active operations. Refuse piles are a major source of acid drainage in some areas and washery residue spillage is a frequent source of the fine coal and silt pollution common in some streams.

For field inventory purposes, a coal mine drainage source is considered to be a surface or underground location resulting from the handling or extraction of coal, containing minerals whose solution by contact water is resulting in a highly mineralized drainage. A drainage of greater than one gallon per minute is considered large enough to be included in a source inventory.

FORMATION OF POLLUTANTS IN COAL MINE DRAINAGE

Although the exact reaction process is still not fully understood, the formation of acid mine drainage is generally illustrated by the equations shown below. The initial reaction that occurs when iron sulfide minerals are exposed to air and water produces ferrous sulfate and sulfuric acid.

$$\underset{\text{(pyrite)}}{2FeS_2} + 7O_2 + 2H_2O \longrightarrow \underset{\text{(ferrous sulfate)}}{2FeSO_4} + \underset{\text{(sulfuric acid)}}{2H_2SO_4}$$

Subsequent oxidation of ferrous sulfate produces ferric sulfate.

$$4FeSO_4 + 2H_2SO_4 + O_2 \rightleftharpoons \underset{\text{(ferric sulfate)}}{2Fe_2(SO_4)_3} + 2H_2O$$

Depending on physical and chemical conditions, the reaction may then proceed to form ferric hydroxide or basic ferric sulfate.

$$Fe_2(SO_4)_3 + 6H_2O \rightleftharpoons \underset{\text{(ferric hydroxide)}}{2Fe(OH)_3} + 3H_2SO_4$$

and/or

$$Fe_2(SO_4)_3 + 2H_2O \rightleftharpoons \underset{\text{(basic ferric sulfate)}}{2Fe(OH)(SO_4)} + H_2SO_4$$

Pyrite can also be oxidized by ferric iron as shown below.

$$FeS_2 + 14Fe^{+3} + 8H_2O \longrightarrow 15Fe^{+2} + 2SO_4^{-2} + 16H^{+}$$

Regardless of the reaction mechanism, the oxidation of one molecular weight of pyrite ultimately leads to the release of four molecular weights of sulfuric acid (acidity).

Other constituents found in mine drainage are produced by secondary reactions of sulfuric acid with minerals and organic compounds in the mine and along the stream valleys. Such secondary reactions produce concentrations of aluminum, manganese, calcium, sodium, and other constituents in the drainage water. These mine drainage constituents, along with iron and sulfate, are indicators of mine drainage pollution that may persist long after the acid in the drainage has been neutralized.

Although there are conflicting opinions among researchers as to the importance of micro-organisms in the productions of mine drainage pollution, there is evidence to indicate that micro-organisms do contribute to pyrite oxidation. A number of bacterial species including *Thiobacillus thiooxidans*, *Thiobacillus ferrooxidans*, and *Ferrobacillus ferrooxidans* have been isolated from mine drainage waters.

WATER QUALITY EVALUATION

The intensity of coal mine drainage pollution is evaluated by measurement of various water quality parameters. The most common physical, chemical, and biological parameters used for evaluation are listed in Table 2.

Some of the chemical and physical parameters listed in Table 2 are incorporated in the water quality standards for interstate streams that have been promulgated under the Water Quality Act of 1965. The most commonly applied standard that reflects coal mine drainage pollution is pH. Pennsylvania's established standards call for a pH of not less than 6.0 or more than 8.5 for all perennial interstate streams, including those in the Susquehanna, Monongahela and Allegheny River drainages, which are the three major mine-drainage polluted drainages in Appalachia. West Virginia standards call for pH levels of not less than 6.0 or greater than 8.5, except for certain streams in the Monongahela River drainage, where a minimum pH of 5.5 has been established.

In addition to pH, Pennsylvania standards specify maximum total iron and average total dissolved solids levels of 1.5 mg/l and 500 mg/l, respectively, for most interstate streams affected by mine drainage. Maximum total manganese and maximum sulfate levels are also specified for some stream reaches.

Various analytical methods are available for measuring the physical and chemical parameters listed in Table 2. The current methods to be used within FWPCA and by other specified agencies are given in "FWPCA Official Interim Methods for Chemical Analysis of Surface Waters - September 1968" (Federal Water Pollution Control Administration, 1968).

Because the pollution of streams by coal mine drainage can be extremely damaging to aquatic life, biological observations and measurements are useful for evaluating the extent of pollution. Streams so polluted generally support only a few species of particularly tolerant plants and animals.

Damages to aquatic life from acid mine drainage are attributed usually to high concentrations of mineral acids, the ions of iron, sulfate, and the deposition of a smothering blanket of precipitated iron salts on the stream bed. In addition, zinc, copper, and aluminum have occurred at lethal concentrations in acid mine drainage; and arsenic and cadmium have been found at threshold concentrations. The toxicities of these elements are compounded by synergism among several of them: zinc with copper, zinc with cadmium, and copper with cadmium.

The toxicities of iron, copper, and zinc solutions are much greater in the acid waters polluted by coal mine drainage than in neutral or alkaline waters. Because of the complex chemical nature of coal mine drainage, it is impossible to assign its toxicity toward aquatic life to any single chemical constituent.

Toxic chemicals in acid mine drainage eliminate sensitive life forms; tolerant forms occasionally flourish to great numbers apparently unaffected by the pollutants. The specialized flora and fauna of acid mine drainage reflect harsh water quality conditions. Fish are usually not found when the pH of a stream is lower than 4.5. Conversely, populations of midge larvae (Tendipes sp.) may develop to nuisance proportions.

A qualitative biological examination of a stream heavily polluted by acid mine drainage (pH 4.0 or lower) may reveal a community structure similar to the following:

(1) Complex Plants

Cattails (Typha sp.) and some mosses; other vascular plant life is generally not found in acid mine drainage.

(2) Algae

Dense flowing mats of species of the green alga Ulothrix are so common as to attract the attention of casual observers; gelatinous mats of chlorophyll-containing flagellates (Euglena spp.) often color stream beds dark green; microscopic examination commonly reveals other species of green algae, including Microspora spp., Microthamnion sp., the flagellate Chlamydomonas sp., great numbers of diatoms Eunotia sp., Pinnularia sp., and Navicula sp., and lesser numbers of Surirella sp.

(3) Benthic Invertebrates

In severely polluted stream reaches, especially near the mine adits from which polluted water flows, no benthos will be found. In less severely polluted reaches, common inhabitants include midges (Tendipes spp. and others), alderflies (Sialis sp.), fishflies (Chauloides sp.), craneflies (Antocha sp. and others), dytiscid beatles, and caddisflies (Ptilostomis sp.). Swampy areas polluted by coal mine drainage contain the above forms, plus water boatmen, dragonflies, damselflies, and mosquitoes. Conspicuous by their absence are crayfish, blackflies, mayflies, stoneflies, and most species of caddisflies.

Table 2 - Physical, chemical, and biological criteria significant in evaluating mine drainage pollution of streams in Appalachia.

1 PARAMETER	2 RANGE OF VALUES OF CONCERN	3 MAJOR WATER USE(S) PROTECTED	4 SOURCE(S) OF CRITERIA	5 USUAL VALUES IN UNPOLLUTED WATERS IN APPALACHIA
1. pH	less than 6.0	uses involving aquatic life	1,2,3,4 (See listing below)	6.0 - 9.0
2. Acidity	sufficient to lower alkalinity below 20 mg/1	uses involving aquatic life	1	less than alkalinity
3. Alkalinity	< 20 mg/1	uses involving aquatic life	1	>20 mg/1
4. Sulfates	> 250 mg/1	domestic and industrial water supply	1,2,3,4	< 20 mg/1
5. Hardness	> 250 mg/1	domestic and industrial water supply	1,2,3,4	<150 mg/1
6. Total iron	> 1.0 mg/1	uses involving aquatic life, domestic and industrial water supply	5	< 0.3 mg/1
7. Manganese	> 1.0 mg/1	uses involving aquatic life, domestic and industrial water supply	2,4	< 0.05 mg/1
8. Aluminum	> 0.5 mg/1	uses involving aquatic life	1,4	absent
9. Suspended solids	> 250 mg/1	uses involving aquatic life	1	<100 mg/1 (except during high runoff periods)
10. Dissolved solids	> 500 mg/1	domestic and industrial water supply	1,2,3,4	< 250 mg/1
11. Complex plants	Vascular plants community restricted; limited to *Typha* sp.; mosses present.	uses involving aquatic life	6	great variety of plant life
12. Simple plants	Algal community restricted; dominated by one to eight species, especially *Ulothrix*, *Euglena*, and pennate diatoms.	uses involving aquatic life	6,7	great variety of algae
13. Benthos	Lacking in mayflies, stoneflies, most caddisfly species, crayfish and blackflies. *Tendipes* or *Sialis* may be very abundant.	uses involving aquatic life	6	great variety of benthos
14. Fishes	Lacking or much restricted.	fishing	6,8	varied fish fauna

List of sources in Table 2, complete references listed in pages 268 to 271.

1. U. S. Dept. of the Interior, 1967.
2. Pennsylvania Sanitary Water Board, 1967.
3. U. S. Dept. of Health, Education and Welfare, Public Health Service, 1962.
4. McKee and Wolf, 1963.
5. Ellis, 1937.
6. Lackey, 1938 and 1939.
7. Joseph, 1953.
8. Parsons, 1957.

(4) Fish: Absent

Upstream reaches, not polluted by acid mine drainage, might support several species of rooted and floating vascular plants, twenty or thirty species of algae, fifteen or twenty species of benthic invertebrates, and a mixed community of fishes. Severely polluted stream reaches might support only three or four species of algae; in less severely polluted reaches, only one or two species of vascular plants, three or four species of algae, three or four species of benthic invertebrates, and no fish.

Sampling Methods Include:

(1) Periphyton

Qualitative samples may be scraped from the stream bed or from any submersed object. Preferably, unpreserved samples should be examined; if live examination is impracticable, samples may be preserved in 5% formalin, 70% isopropyl alcohol, Lugol's iodine solution, or King's fluid (Joseph, 1953). Quantitative samples have been collected by the Acid Mine Pollution Control Demonstration Program by submerging glass microscopic slides secured to clay bricks with adhesive putty. Preservation or quantitative samples is by the same methods as listed above.

(2) Algae

Collection by routine water samples collected 1-foot beneath surface; preservation and examination techniques as discussed in Standard Methods (American Public Health Association and others, 1965, p. 644).

(3) Benthos

Qualitative samples may be taken by screening river bed materials, examining rocks, and other submerged objects. Quantitative samples may be taken by Petersen dredge or Surber square foot sampler. In using artificial substrata, inert materials should be used, because most metals are quickly corroded by acid mine drainage. Benthic invertebrates may be preserved in 10% formalin.

(4) Fish

It is recommended that all polluted streams be examined for the presence of fish. Standard collection methods, such as poisoning, netting, and electroshocking may be used.

Preceding page blank

DAMAGES

Discharge of acid coal mine drainage to surface waters changes the water quality by:

1. (1) Lowering the pH
2. (2) Reducing the natural alkalinity
3. (3) Increasing the total hardness
4. (4) Adding undesirable amounts of iron, manganese, aluminum, sulfates, and other elements and suspended material.

Some tangible damages resulting from these quality changes that can be evaluated in monetary terms are:

1. (1) The cost to municipal and industrial water treatment plants for the required additional treatment of polluted water and early replacement of equipment damaged by polluted water.
2. (2) The cost of early replacement of steel or iron structures and equipment such as culverts, bridges, locks, boat hulls, steel barges, pumps and condensers. Concrete structures may also be damaged.

Damages to recreational uses and aesthetic values are difficult to measure in economic terms, but are important. Such damages are:

1. (1) Streams may be rendered less desirable or unusable for water-related recreational uses such as fishing, boating, water skiing, swimming, camping, and picnicking.
2. (2) The elimination or alteration of biological life.
3. (3) The lowering of property values along polluted streams.

The details of the damages to some specific water uses are;

Water Supplies

Adverse effects to water supplies are caused by the increased concentrations of acidity, iron, manganese, hardness, color, silt, coal fines, and sulfates that may result from coal mining and/or coal processing operations.

High acidity and low pH increase corrosivity and may interfere with water treatment processes such as coagulation and softening. Iron and manganese in concentrations above 0.3 mg/l and 0.05 mg/l, respectively, cause aesthetic problems such as staining of laundry and undesirable tastes. Hardness causes excess soap consumption and boiler scaling. These undesirable characteristics can be eliminated by treatment of the polluted water but water treatment costs are thereby increased.

Recreation

The discharge of mine drainage and coal mining or coal processing wastes into streams and lakes impairs their quality for fishing and makes them unattractive for boating, water skiing, swimming, and even picnicking. The destruction of aquatic life by mine drainage results from the toxicity of chemicals in mine drainage and from the blanketing action of iron precipitates and other suspended materials. Acid mine waters are harmful to most aquatic organisms. Fish are not only killed directly by mine drainage, but are also unable to survive because of the destruction of important food elements. The specialized flora and fauna that develop in mine drainage polluted waters may produce nuisance conditions such as large hatches of midges.

PRESENT CONDITIONS

Methods of Study

The extent of stream pollution by coal mine drainage in Appalachia has been determined and an initial inventory of the sources of drainage pollution has been made in a substantial proportion of the region. The studies leading to the accumulation of these data have been carried out by personnel in the Ohio Basin, Middle Atlantic and Southeast Regions of FWPCA in cooperation with the States and other Federal agencies.

For the most part, this study was coordinated with continuing FWPCA programs in mine drainage pollution control and for reasons such as local magnitude of the problem, geography, and available regional resources, some areas of the Appalachian Region are more completely described than others.

Description of mine drainage pollution in the Appalachian Region is given by sub-areas, which are discrete drainage basins with the exception of the Anthracite area that includes portions of the Susquehanna and Delaware watersheds. The sub-areas are described in a geographic sequence, the 5 areas in the Delaware, Susquehanna, and Potomac River basins are described first, followed by the 14 sub-areas of the Ohio River basin and an area in the Black Warrior River drainage, Alabama. Discussion of the Black Warrior basin is combined with that of the Tennessee basin because of the close geographic relation of the two basins and the similarity of the pollution problems in the two areas.

Generally, the determination of those streams significantly polluted by mine drainage was first made by consulting with other Federal and State agencies, by review of published and unpublished reports, and in some cases by field reconnaissance. On the basis of this initial work, stream sampling stations were established on many of the streams. From one to eight samples were taken at each location, most of them during the summer months of 1966, and appropriate chemical analyses were made. Water quality data were examined with regard to their compliance with water quality criteria and standards in making final determinations of the extent of stream pollution from mine drainage.

Acidity loadings are frequently given within this report as net acidity. Net acidity is the measured acidity less the measured alkalinity. Net acidity and measured acidity loadings are the same at pH values below 4.5, since there is no alkalinity to be subtracted. In samples with a pH above 4.5, reporting of net acidity loadings gives a more conservative appraisal of stream conditions than does reporting of total measured acidity loadings.

Streams are shown in the sub-area maps as being continuously affected by mine drainage or intermittently or potentially affected. Continuously affected streams are those that have been observed to be significantly degraded all or nearly all of the time. Intermittently or potentially affected streams are those that have been observed to be significantly degraded from time to time or where the potential exists and intermittent pollution probably occurs. Almost all of the streams in northern Appalachia that are classed as intermittently or potentially affected are known to be significantly affected. The potentially affected streams are almost entirely in Kentucky, Tennessee, and Alabama.

Field crews have located, sampled, and described point sources of mine drainage in the Susquehanna, Monongahela, and most of the Allegheny basins and in portions of some other sub-areas. Field work in the Allegheny River basin has been done cooperatively with the State of Pennsylvania. This work has usually involved only one visit to a drainage source and the flows and quality measurements that have been made are generally representative of dry summer conditions. For this reason, the amount of acid drainage observed to originate from the individual sources totals much less than the year-around average amount carried by streams in a drainage basin.

Throughout the report, the sulfate ion concentration and sulfate ion loading in the Region's streams has been used as an indicator of the amount of acid formed in sub-areas of the Region. This procedure has been used because one molecular weight of sulfate is formed for each molecular weight of acid that results from pyrite oxidation. In addition, sulfate ion is present in relatively low concentrations in unpolluted streams, it is a persistent element, and the analysis for sulfate is relatively reliable.

SUB-AREA DISCUSSIONS

Anthracite Area

Description

Anthracite coal deposits in the study area lie in four individual fields in northeastern Pennsylvania (Figure 2). The coal fields, underlie a total area of 484 square miles, and are designated the Northern field, Western Middle field, Eastern Middle field, and Southern field. The area includes portions of Carbon, Columbia, Dauphin, Lackawanna, Lebanon, Luzerne, Northumberland, Schuylkill, Susquehanna, and Wayne Counties.

All of the Northern field lies within the Susquehanna River basin. Approximately 50 percent of the Eastern Middle field, 90 percent of the Western Middle field, and 40 percent of the Southern field are drained by the Susquehanna River and its tributaries. The remainder of the fields drain to the Delaware River through its tributaries, the Lehigh and Schuylkill Rivers.

Major streams draining the Anthracite area are as follows:

Name	Drainage Area (square miles)	Mile Pt. of Confluence
Susquehanna River Basin		
Lackawanna River	346	195
Nescopeck Creek	172	159
Catawissa Creek	155	143
Shamokin Creek	138	122
Mahanoy Creek	155	112
Mahantango Creek	164	102
Wiconisco Creek	116	96
Swatara Creek	567	60
Delaware River Basin		
Lehigh River	1,373	
Schuylkill River	1,916	

The Anthracite area lies entirely within the Valley and Ridge Province of the Appalachian·Highlands, the principal feature of which is a series of canoe shaped valleys in which the coal deposits are located. The ridges trend generally northeast to southwest with elevations varying from 1,400 to 2,700 feet.

All the rocks of the area are of sedimentary origin and range in age from Pennsylvanian to Silurian. The Pennsylvanian age Llewellyn formation contains the most economically important deposits of Pennsylvania anthracite coal, with the underlying Pottsville Formation containing the remaining reserves. These formations consists of alternating beds of sandstone, shale, fireclay, black carbonaceous slate, and coal. The Llewellyn and Pottsville formations contain from 12 to 26 minable coal beds. Coal beds range from several inches to many feet thick. The Great Mammoth bed has a thickness, in areas, in excess of 60 feet.

In the Northern field, coal deposits are contained within a canoe-shaped syncline which has a flat bottom and steep sides that outcrop along the mountain ridges. The field is about 62 miles long, 5 miles wide and covers an area of approximately 176 square miles. The Northern field is separated into two coal basins, the Lackawanna and Wyoming, near Old Forge, Pennsylvania, by a geological structure.

The Eastern Middle field, encompasses an area of approximately 33 square miles and consists of a number of long, narrow coal basins trending east to west. Most of the coal seams lie above surface drainage level and are drained by tunnels driven expressly to provide gravity drainage to surface streams. Numerous mine openings, slopes, drifts, and short tunnels also provide drainage.

The Western Middle field consists of a series of parallel, irregularly shaped coal basins covering an area of approximately 120 square miles. The field, about 42 miles long and from two to five miles wide, contains strata that locally may lie nearly horizontal or dip steeply. Deposits resemble those in the Eastern Middle field, except that most of the deposits lie below surface drainage level and are now flooded.

The Southern field, about 70 miles long and 1 to 6 miles wide, covers an area of about 200 square miles. The geologic structure of the Southern field is more complicated than that of the other fields. The coal beds dip more steeply than elsewhere and are more complexly faulted. The largest tonnage of anthracite reserve lies in this field.

Approximately 95 percent of the Nation's true anthracite lies in Pennsylvania in the watersheds of the Susquehanna and Delaware Rivers. Since 1808, over five billion tons of anthracite has been mined. Remaining anthracite coal reserves within the Susquehanna River basin have been estimated at 22.6 billion short tons. Recoverable reserves are estimated to be 11.6 billion tons (U.S. Geol. Survey, 1968).

Peak production was slightly more than 100 million tons per year. Production decreased gradually to a low of about 16.5 million tons in 1964. Projected estimates of anthracite production for the area are as follows:

Projected Anthracite Production (written communication U.S. Bureau of Mines)

	1970	1985	2020
Susquehanna Basin	5,900	3,200	2,500 thousand tons
Delaware Basin	5,300	4,200	9,500

Mine Drainage Sources and Their Effect on Stream Quality

There are presently about 160 significant mine drainage sources (active and inactive) and 84,200 acres of unreclaimed surface-mined land in the Anthracite area. The drainage from these underground and surface sources is causing continuous significant degradation of 260 miles of streams and intermittent significant pollution of 250 miles of streams.

The distribution of and pollution loads contributed by major mine drainage discharge sources within the Anthracite area are shown on the following page.

Figures 3, 4 and 5 show that for the years for which data are available the average total sulfate loadings were about 190 tons/day in the Lehigh River at Catasaqua, 425 tons/day in the Schuylkill River at Berne, and 2,000 tons/day in the Susquehanna River at Danville. Of the total average sulfate loading of 2,615 tons/day at these three locations about 2,000 tons/day resulted from mine drainage originating in the Anthracite area. In addition, mine drainage sulfate loadings in Shamokin Creek, Manahoy Creek, and Swatara Creek total about 300 tons/day, bringing the total sulfate loadings resulting from mine drainage in the Anthracite area to 2,300 tons/day. This figure can be considered to indicate the average daily quantity of mine drainage acidity formed in the Anthracite area during the years for which data are available. Field measurements of active drainages indicate that of the 2,300 tons/day of acidity formed in the area about 350 tons/day enters streams unneutralized. The amount of mine drainage indicators entering streams in the Anthracite area each year can be considerably greater or lesser than the average amount depending on mining activity, amount of rainfall, and other related factors.

A detailed discussion of the mine drainage sources in the Anthracite area, and their effect on stream quality follows:

Mine Drainage Sources and Net Acidity Contributions Anthracite Area

Area Sub-Area	Active Operations		Inactive Operations						Total Sources	
	Underground Mines		Underground Mines		Surface Mines		Other Sources[1]			
	No. of Sources	Net Acidity[2]	No. of Sources	Net Acidity	No. of Sources	Net Acidity	No. of Sources	Net Acidity	No. of Sources	Net Acidity
Anthracite Area										
Lackawanna River			13	83,000					13	83,000
Wyoming Valley	2	86,000	3	142,000					5	228,000
Nescopeck Creek			4	64,800					4	64,800
Catawissa Creek			6	27,800					6	27,800
Shamokin Creek	2	6,600	6	27,400	1	200			9	34,200
Mahanoy Creek	5	28,900	13	28,900					18	57,800
Mahantango Creek	22	2,900	10	2,200					32	5,100
Wiconisco Creek			5	3,600					5	3,600
Swatara Creek	5	2,800	13	7,700	2	700	1	100	21	11,300
Lehigh River			8	9,000	3	300			11	9,300
Schuylkill River	4	2,800	33	16,300					37	19,100
(Sub-Total)	40	130,000	114	412,700	6	1,200	1	100	161	544,000

---

[1] Other inactive sources are abandoned refuse piles and seepages that can not be identified with specific sources.

[2] Net acidity in pounds per day.

A. Lackawanna River

Changes in mining activity and mine drainage discharge points have greatly altered the quality of the Lackawanna River within the past 10 years. Prior to 1960, extensive mining with associated mine drainage severely degraded stream quality. Declines in demand for anthracite coal, the cost of pumping high volumes of water, and other circumstances gradually forced the abandonment of most of the deep mines and inactive mines account for virtually all drainage pollution in the area.

Cessation of mining and mine water pumping has resulted in a very significant increase in stream alkalinity although some mine drainage influence on stream quality persists. In January 1961, the mine water pools which had been developing in the abandoned underground workings broke through the surface in the form of a gravity discharge to the Lackawanna River at Duryea, approximately two miles from its mouth. The largest discharge of mine drainage in the Anthracite field is a combination of the Duryea gravity discharge and the discharge from a borehole, which was subsequently drilled one mile upstream at Old Forge in order to stabilize the level of the underground pools. The combined discharges contribute an average flow of about 58 mgd, an acid load of approximately 66 tons/day net acidity, and an iron load of approximately 31 tons/day.

Although most of the mine water in the Lackwanna River watershed discharges to the river through the Duryea and Old Forge discharge points, as illustrated in Figure 6, water quality in the river is also influenced by other mine drainage discharges.

The initial effect of mine drainage on stream quality is evident immediately above Carbondale and downstream from Elk Creek. Based on an acidity-alkalinity balance, this reach of the Lackawanna River receives a net acid loading of at least 0.5 tons/day from the combined flows described above. Between Carbondale and Old Forge, the river receives mine drainage contributed primarily by the Jermyn Water Tunnel, which contributes approximately 2.7 tons/day net acidity.

Between the entry of the Jerwyn discharge and the confluence with the Susquehanna River, the Lackawanna River receives the Duryea and Old Forge discharges. These discharges overcome the stream's residual alkalinity and were primarily responsible for the acid loading of 23.5 tons/day net acidity discharged at the mouth of the Lackawanna River during the sampling period. The Lackawanna River discharge does not deplete the Susquehanna River's alkalinity reserve. However, iron and manganese loadings originating in the Duryea and Old Forge discharges are responsible for substantial degradation of the quality of the Susquehanna River.

Variation of mine drainage indicators throughout the length of the Lackawanna River is illustrated in Figures 6 and 7. At its mouth the pH is generally between 4 and 6. The acidity concentration is about 150 mg/l and iron and manganese concentrations are normally in the 50 mg/l and 10 mg/l range, respectively.

B. Susquehanna River-Lackawanna River to Nescopeck Creek

The quality of the Susquehanna River is impaired in this reach by mine drainage contributed by the Lackawanna River and prior to November 1967 by discharges originating in the Wyoming Valley portion of the Northern Anthracite field. Tributary streams contributing most of the mine drainage originating in the Wyoming Valley included: Mill Creek, Solomons Creek, Warrior Run, Nanticoke Creek, and Newport Creek (Figures 8 and 9). These streams conveyed discharges from large mine-pumping stations and the water quality of the streams approximated the qualitites of the discharges.

All of the pumping operations that contributed a significant amount of acid to the Susquehanna River were operated by the Blue Coal Company. The company operated a total of 27 pumps and 17 locations. The total flow of pumped discharges averaged 62 mgd the acid loading averages 180 tons/day net acidity and the iron loading averages 67 tons/day.

Under the direction of the Pennsylvania Sanitary Water Board, the Blue Coal Company regulated its discharges in accordance with streamflow, pumping only as necessary to prevent flooding of the active mines during low streamflow periods. Calculations based on pumping records and discharge and stream quality records indicate the following contributions from major sources during the period of sampling in the area -- August 1965:

a. Mill Creek - 42.5 tons/day net acidity from the Delaware pumps.

b. Solomons Creek - 13.5 tons/day net acidity from Huber (7.5 tons/day) and the treated South Wilkes-Barre #5 discharge (6 tons/day). The latter discharge is permitted only with treatment during low flow periods and was active only during the period August 19-31.

c. Warrior Run - 2 tons/day net acidity originating in discharges from Sugar Notch West (0.5) and Sugar Notch shaft (1.5 tons/day).

d. Naticoke Creek - 12 tons/day from the Askam pumped discharge. The Loomis outfall, permitted with treatment during the low flow period, was operated only 53 hours during the month and is not considered here.

e. Newport Creek - 43 tons/day net acidity and 9 tons/day total iron from the Wanamie mining complex.

Although the Susquehanna River received sizable acid contributions from the pumped discharges during the survey period, its alkaline reserve was not seriously threatened. Other mine drainage indicators, particularly manganese and sulfates, were, however, present in relatively high concentrations.

Samples collected in August 1966 at mile 196 upstream from the Lackawanna River and at mile 179 downstream from all significant Northern Anthracite field mine drainage sources indicate reduction in alkalinity and increases in other mine drainage indicators through the reach. Alkalinity dropped from about 84 mg/l to 38 mg/l. Iron, manganese, and sulfate increased from 0.1, 0.09, and 30 mg/l to about 0.3, 1.5, and 190 mg/l, respectively. During the sampling period iron concentrations in this reach were abnormally low. Other data available indicate that the change in concentrations of iron and other mine drainage indicators through the reach is considerably more dramatic under other flow conditions.

In October 1967, the high cost of pumping water and other factors combined to force the Blue Coal Company to discontinue mining operations in areas that required extensive pumping. Essentially all of the pumping was discontinued. It was originally estimated that mine water pools would fill and overflow in two years, but very rapid filling required that the Pennsylvania Department of Mines and Mineral Industries begin pumping in 1968 to prevent flooding and surface subsidence. Pumping is presently from the Delaware Pool. It is planned that, in the future, pumping will be from two locations.

C. Susquehanna River - Nescopeck Creek and Below

Downstream from Nescopeck Creek, stream quality rapidly improves. Downstream tributaries draining the Anthracite area contribute mine drainage, but do not significantly affect stream quality. Biological surveys disclosed significant degradation of aquatic life in the reach from the Lackawanna River to Nescopeck Creek and slight effect further downstream. Periodic degradation of stream quality downstream from Nescopeck Creek has been observed during periods of high streamflow following extended low flow periods. Iron salts that precipitate upstream from Berwick during low flow periods are scoured out during high flows and are evident downstream to the confluence with the West Branch Susquehanna River.

1. Nescopeck Creek

The quality of the upper reaches of Nescopeck Creek above its confluence with Little Nescopeck Creek is not significantly degraded by mine drainage. In fact, this 10-mile reach is classified as a trout stream by the Pennsylvania Fish Commission. Below the confluence, however, stream quality is degraded by mine drainage from Little Nescopeck Creek and Black Creek.

The contribution of approximately 3.5 tons/day net acidity by Little Nescopeck Creek overcomes Nescopeck Creek's natural alkaline reserve and renders it an acid stream. The mean acidity concentration in the Nescopeck Creek immediately downstream from the confluence with Little Nescopeck Creek was found to be 240 mg/l, the mean manganese concentration (8 mg/l) and the total iron concentration (6.5 mg/l). The prime source of pollution of Little Nescopeck Creek is the Jeddo Tunnel, which serves as a gravity discharge point for a large area of abandoned deep mine workings in Black Creek coal basin in the Western Middle anthracite field. The tunnel discharges an average of about 20 mgd with an acid loading of 49 tons/day net acidity.

The quality of Nescopeck Creek improves slightly from its confluence with Little Nescopeck Creek to its mouth. Within this reach, Black Creek contributes sizable loadings of mine drainage indicators, but concentrations of mine drainage indicators are less than those in Nescopeck Creek. The mixture of the two streams thus slightly improves the quality of Nescopeck Creek. Black Creek receives mine drainage discharges from the Gowan and Derringer drainage tunnels, the major mine drainage contributors in the watershed. In addition to mine drainage pollution, Little Nescopeck Creek and Black Creek receive coal silt from coal-processing operations and surface runoff from piles of coal fines.

2. Catawissa Creek

As a result of mine drainage contributions, Catawissa Creek is an acid stream throughout most of its length (Figures 10 and 11). Approximately 38 miles from its mouth, the stream, which at that point is normally alkaline although bearing evidence of mine drainage contributions, is diverted underground in an abandoned surface mining complex that has completely disrupted surface drainage patterns. The stream then apparently flows through abandoned deep mine workings for a distance of approximately 4,000 feet, emerging as the Green Mountain Water Level Tunnel discharge. The stream, bearing an acid load of about 150 tons/day net acidity, is further degraded about three miles downstream by the contribution of a total of about 12 tons/day net acidity from two drainage tunnels, Audenreid and Green Mountain. The stream never recovers from this heavy acid loading.

Tomhicken Creek, with its contribution of 0.9 tons/day net acidity, constitutes the only other significant contributor of acid and other mine drainage indicators. Its contribution does not, however, significantly degrade the quality of Catawissa Creek, since pollutant concentrations are somewhat lower than those in the receiving stream. Most of the acid in Tomhicken Creek originates from the Cox #3 drainage tunnel, which contributed about 0.6 tons/day net acidity during the survey.

Although all of the known mine drainage discharges enter Catawissa Creek in the upper one-third of its length, the weak natural alkalinity and relatively small flow of downstream tributaries are not adequate to neutralize the heavy acid loadings that enter in the headwaters. Catawissa Creek contributes approximately 9.2 tons/day net acidity to the Susquehanna River. This loading is about 80 percent of the largest single contribution, the Audenreid Drainage Tunnel.

Unlike many of the streams in the Anthracite area, Catawissa Creek is not significantly influenced by coal silt, because there are no active coal processing operations in the drainage area.

3. Shamokin Creek

Shamokin Creek is an acid stream throughout 28 miles of its 35 mile length (Figures 12 and 13). The remaining seven miles, the extreme headwaters, although alkaline, were found to have high concentrations of mine drainage indicators, particularly iron and manganese. As shown in Figure 12, downstream from mile 29 the stream is rendered acid by mine drainage contributed by the North Branch Shamokin Creek and the Excelsior Drainage Tunnel. Although the acidity decreases fairly uniformly from about 200 mg/l at this point to about 100 mg/l at the mouth, the acid loading increases from about 4.5 tons/day net acidity to about 18.7 tons/day net acidity in the next 10 miles, then remains constant the remaining 18 miles to the mouth.

As shown in Figure 13, the total iron concentration reaches a peak of 147 mg/l at mile 23 then declines to less than 20 mg/l at its mouth. Mean manganese concentrations range from 6 mg/l to 3 mg/l along the length of the stream. Sulfate concentrations range from 470 mg/l at mile 22 to 430 mg/l at the mouth.

In the Shamokin Creek watershed, all mine drainage discharges enter in the headwaters area, which is typical of the Anthracite fields. Seven major discharges were located in the upstream third of Shamokin Creek drainage. All but one of the discharges originate in underground mines, although they are undoubtedly influenced by surface water diverted underground in areas disturbed by surface mining. At the time of sampling, the seven major discharges contribute a flow of 13.1 mgd and 19 tons/day net acidity

Active underground mines contribute 19 percent of the net acidity load and inactive underground mines contribute 80 percent. The pumped discharge from the Glen Burn Colliery, along, contributes 15 percent.

In addition to constituents attributable to mine drainage, the stream is heavily laden with coal silt, much of which apparently originates at coal cleaning and processing operations.

4. Mahanoy Creek

Mahanoy Creek, although contributing a loading of approximaterly 0.5 tons/day net alkalinity to the Susquehanna River, is one of the most severly degraded streams draining the Anthracite area. The source of stream quality degradation is alkaline mine discharges that contain high concentrations of iron, manganese, and other mine drainage indicators. Severe degradation of stream quality was observed throughout the entire 52 mile length of Mahanoy Creek.

Major contributions of mine drainage reach Mahanoy Creek through the following tributaries: North Branch Mahanoy Creek, Waste House Run, Shenandoah Creek, Big Mine Run, and Zerbe Run. In addition, five large deep mine discharges enter Mahanoy Creek directly.

As shown in Figures 14 and 15, the stream's natural alkalinity is overcome in its upper reaches. This is primarily the result of an 0.4 tons/day net acidity contribution from the East Barrier gravity discharge, an intermittent pumped discharge from the Springdale Tunnel, and a 5.2 tons/day net acidity contribution by Waste House Run which originates in predominately pumped discharges.

Alkaline contributions by the Girardville No. 1 and No. 2 drainage tunnels and Big Mine Run overcome the acid residual and increase the stream's alkaline reserve to a peak of approximately 7.5 tons/day at a sampling station downstream from Big Mine Run. This reserve steadily decays to a minimum 0.5 tons/day at the mouth. The largest acid contribution in the portion of the basin downstream from Big Mine Run is Zerbe Run with its loading of 3.9 tons/day net acidity. Zerbe Run receives essentially all of its acid loading from the Trevorton Tunnel discharge which contributed 6 tons/day net acidity during the survey period.

As illustrated in Figure 15, concentrations of mine drainage indicators vary greatly along the length of the stream. Mean manganese concentrations range from 2.7 mg/l to 20 mg/l; mean total iron concentrations range from 3 mg/l to 110 mg/l. Sulfate concentrations range from 1,050 mg/l to 1,500 mg/l throughout most of the length of the stream. Coal silt discolors the stream and practically fills the channel in some reaches.

5. Mahantango Creek

Mahantango Creek is an acid stream throughout approximately 17 miles of its 32 mile length and contributes approximately 1.8 tons/day net acidity to the Susquehanna River.

Essentially all of the mine drainage discharged in the Mahantango Creek basin comes to the surface in the watershed of Rausch Creek, a small (10 square mile drainage area) tributary to Pine Creek; which is in turn a tributary of Mahantango Creek.

Rausch Creek, with its acid loading of 2.5 tons/day net acidity, exhausts the alkaline reserve of Pine Creek at their confluence and renders it an acid stream for the remaining 13 miles of its length. The quality of Pine Creek is slightly improved by water contributed by alkaline tributaries, the largest of which is Deep Creek. Although influenced by mine drainage originating in the Hans Yost Creek watershed, Deep Creek is essentially neutral at its mouth.

As shown in Figure 16, the residual acid loading of about 1.5 tons/day net acidity which reaches Mahantango Creek easily overcomes its weak alkaline reserve and renders it an acid stream to its mouth. The portion of Mahantango Creek upstream from Pine Creek, although low in alkalinity, is of generally good quality. A biological reconnaissance in 1964 determined that this reach supported normal aquatic life.

Upstream from Pine Creek, Mahantango Creek is almost free of all mine drainage indicators and has, in fact, surprisingly low mineral content. For example, its mean sulfate concentration is 7 mg/l. Mean iron and manganese concentrations are 0.4 mg/l and 0.9 mg/l, respectively. Downstream from Pine Creek stream quality is relatively constant. Iron and manganese concentrations are slightly less than 0.6 mg/l. Mean net acidity ranges between 35 and 45 mg/l (see Figure 17).

Mine drainage sources in the Mahantango Creek watershed, although clustered in a relatively small area of the Rausch Creek watershed, are not, as is the case in some of the watersheds already discussed, collected by drainage tunnels. Mine drainage is contributed to Rausch Creek through 22 known pumped discharges and 10 gravity discharges. The largest of the gravity discharges are the Markson and Valley View which are responsible for a total contribution of 0.8 tons/day net acidty.

6. Wiconisco Creek

Wiconisco Creek is an alkaline stream throughout its length and it contributes approximately 3 tons/day net alkalinity to the Susquehanna River. Its quality is degraded by coal silt, and mine drainage indicators for at least a portion of its length.

The major mine drainage sources are the Porter and Keefer drainage tunnels and Bear Creek, which receives mine drainage from two drainage tunnels. All of the major discharges are located in the upper one-third of the stream's length. Figure 18 illustrates the effect on stream alkalinity reserves of the contribution of 3 tons/day net alkalinity by Bear Creek, which neutralizes the .4 tons/day net acidity contributed by the Porter and Keefer Tunnels.

Although iron, manganese, and sulfate concentrations in Wiconisco Creek are temporarily elevated by contributions from Bear Creek, about 25 miles of stream downstream from Bear Creek are of relatively good chemical quality (see Figure 19). A summary of a biological survey of the stream conducted in 1964 reports essentially no aquatic life upstream from Bear Creek. Several species of clean water organisms were collected at the mouth, indicating at least partial recovery from the upstream pollution loadings. Coal silt loadings in the stream are heavy. These apparently originate in coal washeries in the basin.

7. Swatara Creek

Mine drainage renders swatara Creek acid from its headwaters to its confluence with Mill Run, a distance of approximately 24 miles. Streams found to be contributing significant amounts of mine drainage to Swatara Creek during a survey of the basin in October and November 1965 were: Panther Creek, Good Spring Creek, and Lower Rausch Creek. As illustrated in Figure 20, Panther Creek, with its small contribution of net acidity does not significantly affect the alkalinity reserve of Swatara Creek. It does, however, contribute other mine drainage indicators. Figure 20 illustrates how the alkalinity reserve of Sqatara Creek is affected by acidity from Good Spring Creek. Most of the mine drainage in the Good Spring Creek originates in the watershed of Middle Creek, a tributary that enters Good Spring Creek about one mile from its mouth. Lower Rausch Creek contributes a net acid loading of 0.6 tons/day, most of which originates in three drainage tunnel discharges.

As shown in Figure 20, the acid loading in Swatara Creek reached a peak of 1.8 tons/day net acidity at mile 58, immediately downstream from Lower Rausch Creek, and then declined in response to the influence of alkaline tributary streams. As illustrated in Figure 21, stream quality in the headwaters reach fluctuates rather weakly in response to contributions by streams bearing mine drainage. Mean iron and manganese concentrations are about 3.5 mg/l. Sulfate concentrations are normally less than 250 mg/l. Downstream from mile 60, concentrations of all mine drainage indicators decline.

Considerable mining is presently being accomplished in the basin; however, most of the significant mine drainage discharges observed during the survey originate in abandoned mines. About 2.3 tons/day net acidity loading on the stream during the survey could be attributed to four deep mine discharges and the discharge of Middle Creek.

D. Schuylkill River

The Schuylkill River, a tributary of the Delaware River, drains a large portion of the Southern anthracite field. The Schuylkill River is rendered acid at its headwaters, apparently by runoff from refuse piles. Numerous discharges from all source categories add to the acid load upstream from the confluence with Mill Creek. Eleven major discharges to this reach contribute 1.1 tons/day net acidity.

Tributaries discharging significant amounts of mine drainage to the Schuylkill River include Mill Creek, West Branch Schuylkill River, and the Little Schuylkill River.

The Mill Creek receives drainage from four major discharges and contributes approximately 5.5 tons/day net acidity.

The next downstream source of acid is the West Branch Schuylkill River. The West Branch receives drainage from numerous mines of all categories and contributes approximately 2.3 tons/day net acidity. Most of the acid contributed by the West Branch may be attributed to one drainage tunnel which has an acid contribution of 3.4 tons/day.

The Little Schuylkill River is rendered acid at its source by several drainage tunnel discharges and receives additional acid from Wabash Creek (1 ton/day) and Panther Creek (3 tons/day). Although no samples are collected downstream from mine drainage sources, it is believed that the quality of the Little Schuylkill River is degraded by mine drainage throughout its length. Nine major discharges contributing about 3 tons/day net acidity are located in this watershed. Drainage originates in both active and inactive mines. Acid contributed in the headwaters coupled with the acid contributed by Little Schuylkill River renders the Schuylkill River acid downstream to Reading.

Mine drainage discharges and the receiving streams in this subbasin are generally low in iron and manganese concentrations. Net acidity and sulfate concentrations are relatively high. The quality of the Schuylkill River immediately downstream from the West Branch Schuylkill River is representative of the quality of most of its upstream tributaries. On the day of sampling the net acidity was 78 mg/l. Sulfate, iron, and manganese concentrations were 590, 2.5, and 7.8 mg/l, respectively.

Analysis of chemical data obtained by the U.S. Geological Survey at Berne, Pennsylvania, during 1948-1953 and 1957-1959 (Figure 4) shows that total sulfate loadings in the Schuylkill River averaged 425 tons/day. Of the total load, about 393 tons/day resulted from mine drainage, and this figure is considered to indicate the average amount of acidity formed daily in the Schuylkill basin during those years.

E. Lehigh River

Mine drainage contributed to the Lehigh River originates in the eastern edge of the Eastern Middle and Southern anthracite fields. Streams contributing significant amounts of mine drainage to the Lehigh River include: Sandy Run, Buck Mountain Creek, Black Creek, and Nesquehoning Creek. Essentially all the mine drainage in this basin originates in abandoned mines. Upstream from Sandy Run, the Lehigh River is almost neutral with a very low mineral content. Sandy Run with its acid load of 3 tons/day net acidity overcomes the weak natural alkalinity reserve and renders the Lehigh River acid. About 80 percent of the acid loading contributed by Sandy Run originates in the Owl Hole drainage tunnel discharge. Both Sandy Run and Pond Creek, its major tributary, are rendered acid from source to mouth by drainage from six major discharges, three of which are drainage tunnels.

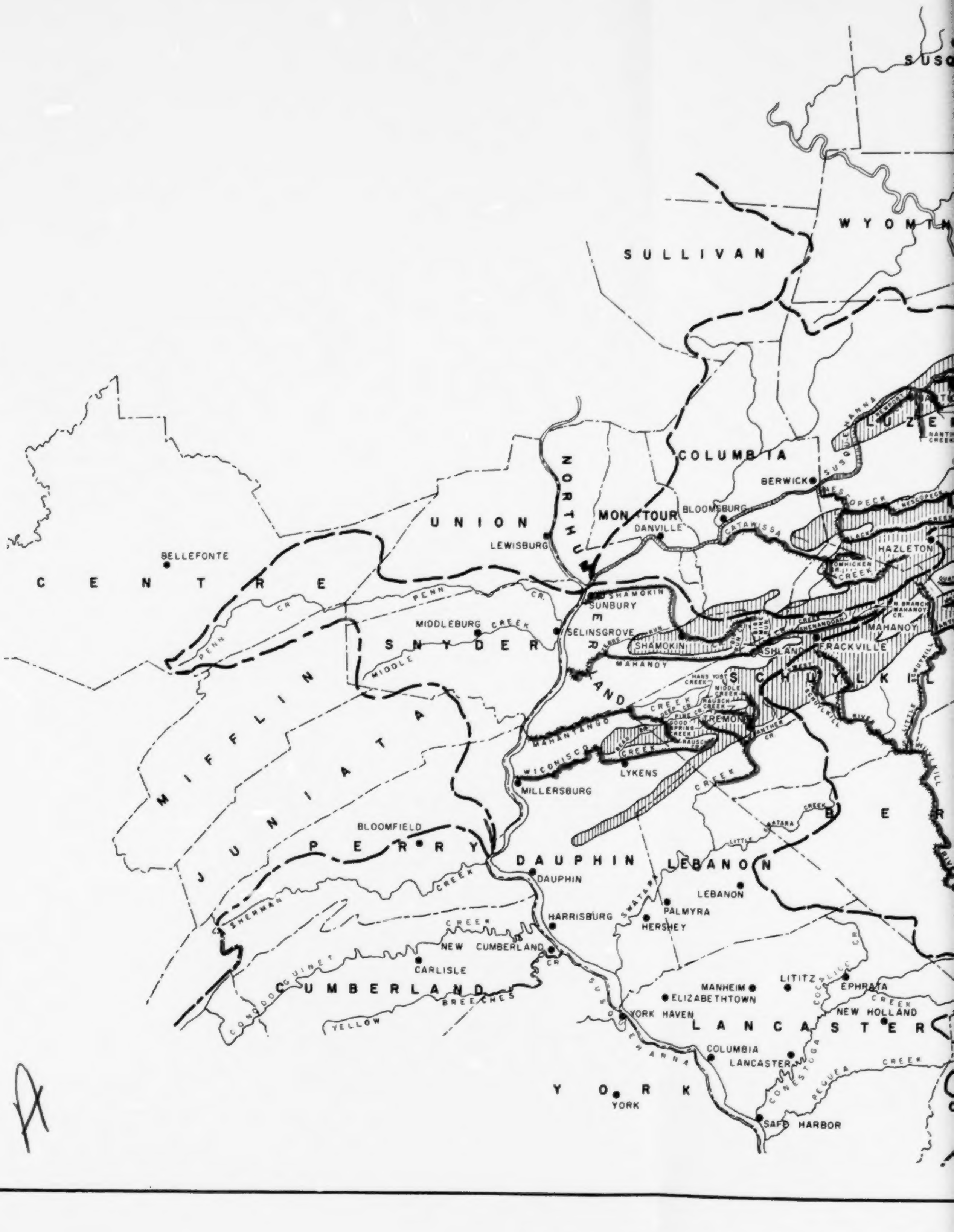
Buck Mountain Creek contributed about 0.9 tons/day net acidity to the Lehigh River on the day of sampling. Essentially all of the acid originates in the discharges from two drainage tunnels, Buck Mountain No. 1 and Buck Mountain No. 2. The tunnels discharge to the extreme headwaters of Buck Mountain Creek and renders it acid throughout its length.

Black Creek contributes approximately 2.7 tons/day net acidity to the Lehigh River, all of which originates in one discharge, the Beaver Meadow (Quakake) Drainage Tunnel. The discharge constitutes most of the flow of Quakake Creek, a tributary of Black Creek. Both streams are rendered acid by the discharge. Because of its large flow, Nesquehoning Creek, although only weakly acid at its mouth (13 mg/l on the day of sampling) contributes a sizable net acidity of 0.6 tons/day to the Lehigh River. The creek is acid throughout its length and receives most of its acid load from two drainage tunnels.

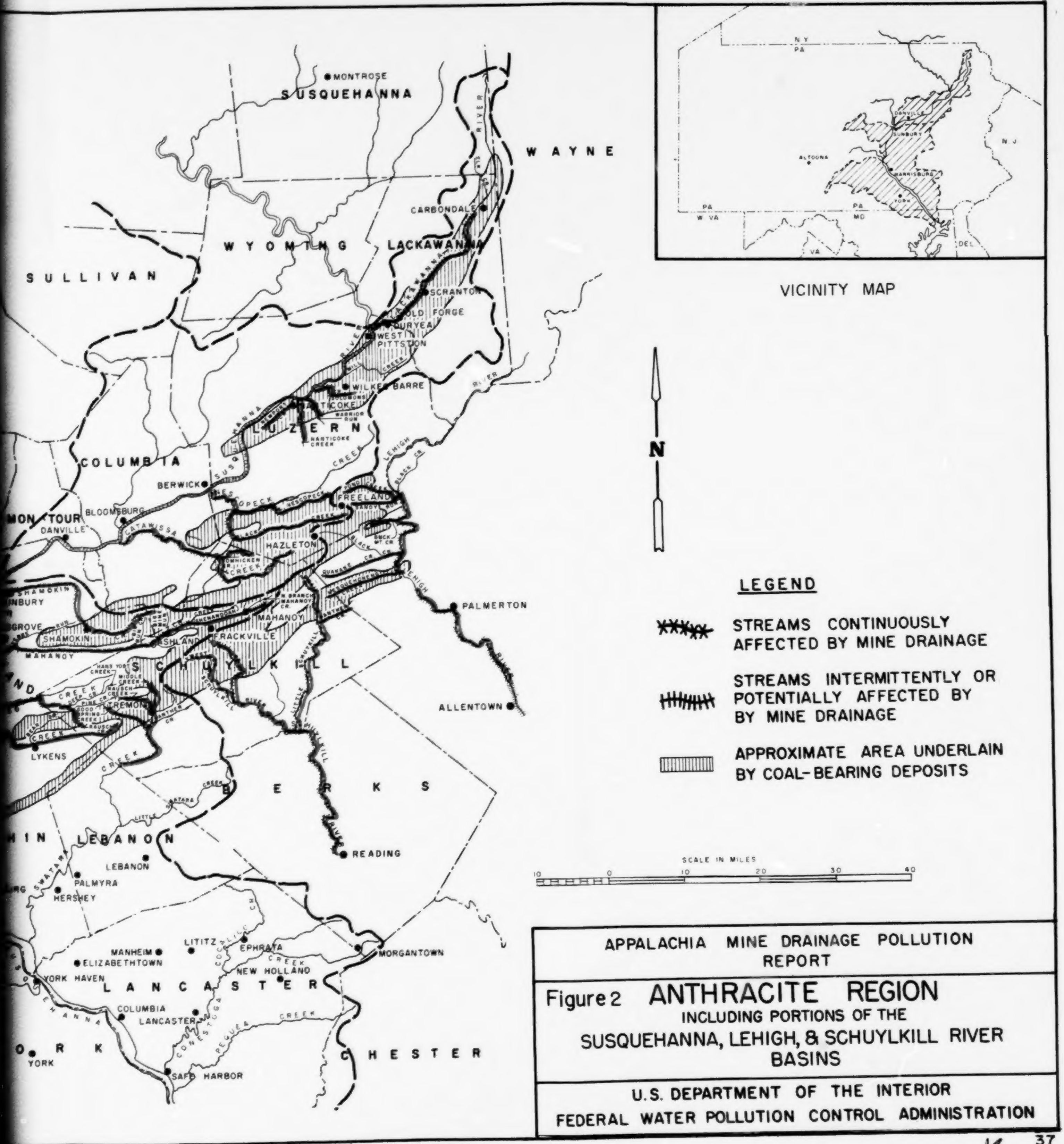
Although no samples were collected downstream from the acid tributaries, other available data indicate that the Lehigh River is severely degraded by the mine drainage downstream to Northampton.

The quality of mine drainage discharges in this basin is similar to that in the Schuylkill River watershed. The iron and manganese concentrations are relatively low, while acidity and sulfate concentrations are high.

Analysis of chemical data obtained by the U.S. Geological Survey at Catasaqua, Pennsylvania during 1945-1952 (Figure 3) shows that for those years the average daily sulfate loading was 190 tons/day. About 90 tons/day of sulfate is estimated to have resulted from mine drainage acidity, and this figure is considered to indicate the amount of acidity formed daily in the Lehigh basin at that time.


SUSQ
WYOMIN
SULLIVAN
LUZER
NANTICOKE CREEK
COLUMBIA
BERWICK
SUSQUEHANNA
NESCOPECK
CATAWISSA
NORTHUMBERLAND
MONTOUR
BLOOMSBURG
DANVILLE
UNION
LEWISBURG
BELLEFONTE
CENTRE
HAZLETON
QUAKAKE
CATAWISSA CREEK
SHAMOKIN
SUNBURY
PENN
CR.
MIDDLEBURG
CREEK
SELINSGROVE
SNYDER
MIDDLE
SHAMOKIN
N. BRANCH MAHANOY CR.
SHENANDOAH
MAHANOY
FRACKVILLE
ASHLAND
MAHANOY
SCHUYLKILL
HANS YOST CREEK
MIDDLE CREEK
RAUSCH CREEK
PINE CR.
GOOD SPRING CREEK
TREMONT
SWATARA
MAHANTANGO
WICONISCO
LYKENS
MILLERSBURG
MIFFLIN
JUNIATA
PERRY
BLOOMFIELD
SCHUYLKILL
LITTLE SCHUYLKILL
BERKS
LITTLE SWATARA
CREEK
DAUPHIN
DAUPHIN
LEBANON
LEBANON
SWATARA
PALMYRA
HERSHEY
HARRISBURG
SHERMAN
CREEK
CONODOGUINET
CREEK
NEW CUMBERLAND
CR
CARLISLE
CUMBERLAND
YELLOW
BREECHES
MANHEIM
ELIZABETHTOWN
LITITZ
EPHRATA
COCALICO CR
CREEK
NEW HOLLAND
YORK HAVEN
LANCASTER
SUSQUEHANNA
COLUMBIA
LANCASTER
CONESTOGA
PEQUEA
CREEK
YORK
YORK
SAFE HARBOR

A


VICINITY MAP
N.Y.
PA
DANVILLE
SUNBURY
ALTOONA
HARRISBURG
YORK
N.J.
PA
W. VA
PA
MD
VA
DEL
N
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
SCALE IN MILES
10 0 10 20 30 40
MONTROSE
SUSQUEHANNA
WAYNE
CARBONDALE
WYOMING
LACKAWANNA
SULLIVAN
SCRANTON
OLD FORGE
DURYEA
WEST PITTSTON
WILKES BARRE
NANTICOKE
LUZERN
COLUMBIA
BERWICK
BLOOMSBURG
MONTOUR
DANVILLE
NESCOPECK
FREELAND
HAZLETON
CATAWISSA
SHAMOKIN
SUNBURY
MAHANOY
FRACKVILLE
ASHLAND
SHAMOKIN
SCHUYLKILL
TREMONT
LYKENS
PALMERTON
ALLENTOWN
LEHIGH
BERKS
READING
LEBANON
LEBANON
PALMYRA
HERSHEY
SWATARA
MANHEIM
LITITZ
EPHRATA
ELIZABETHTOWN
YORK HAVEN
NEW HOLLAND
LANCASTER
COLUMBIA
LANCASTER
MORGANTOWN
CHESTER
YORK
SAFE HARBOR
CONESTOGA
PEQUEA CREEK

APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 2 ANTHRACITE REGION INCLUDING PORTIONS OF THE SUSQUEHANNA, LEHIGH, & SCHUYLKILL RIVER BASINS

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

B

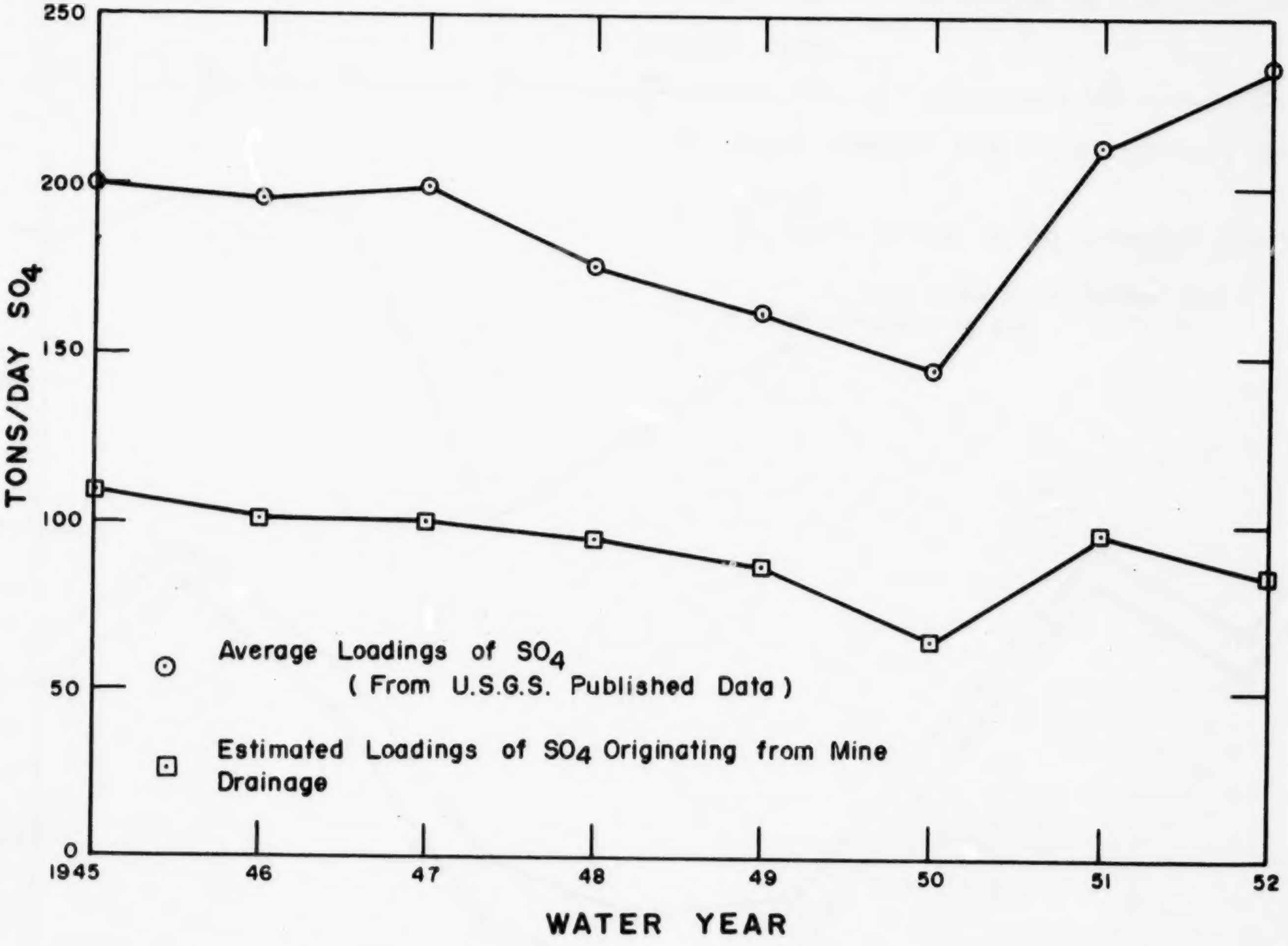


Figure 3. Average loads of total sulfate and sulfate considered to originate from coal mine drainage carried by the Lehigh River at Catasauqua, Pennsylvania.

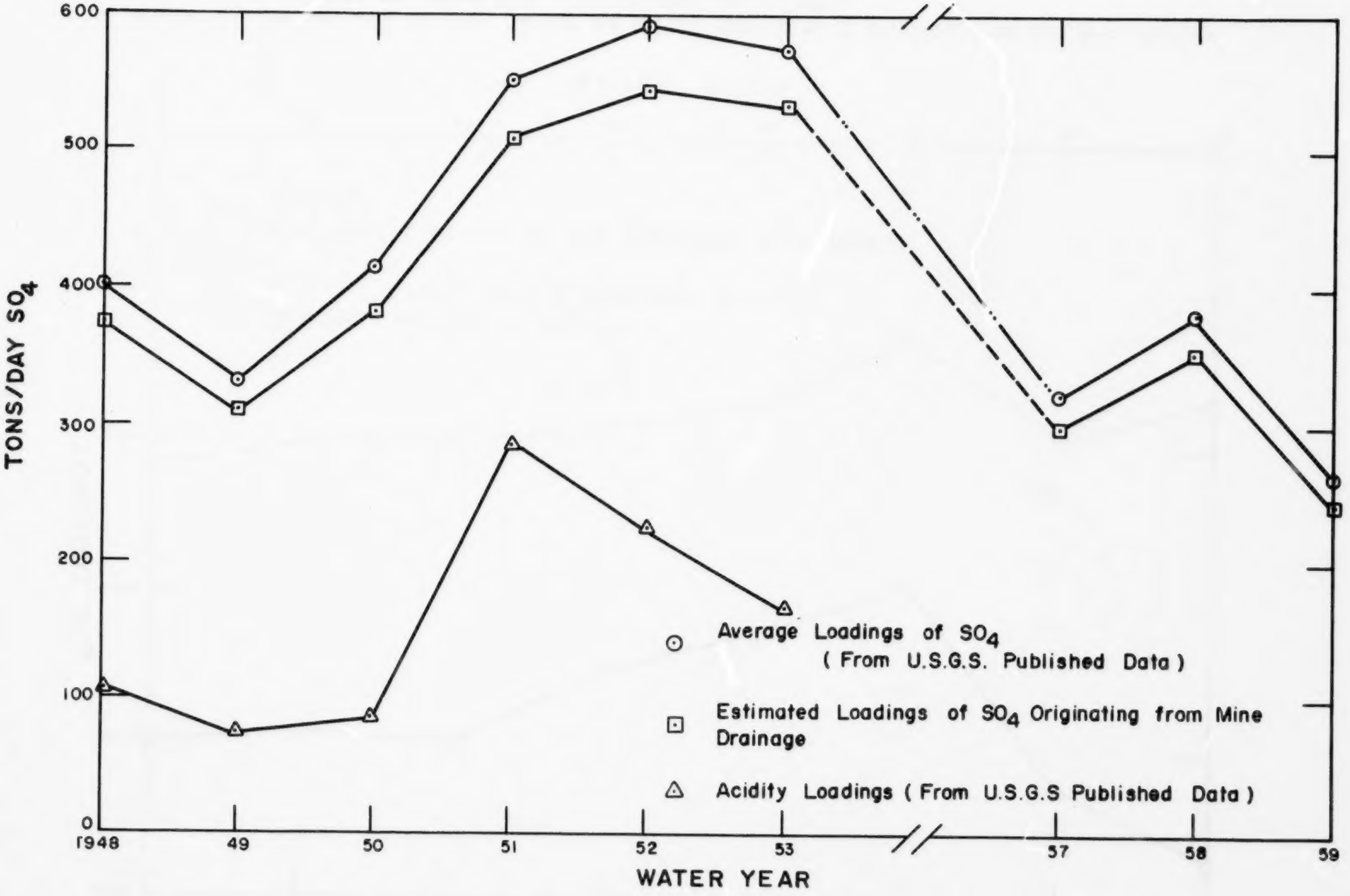


Figure 4. Average loads of acidity, total sulfate and sulfate considered to originate from coal mine drainage carried by the Schuylkill River at Berne, Pennsylvania.

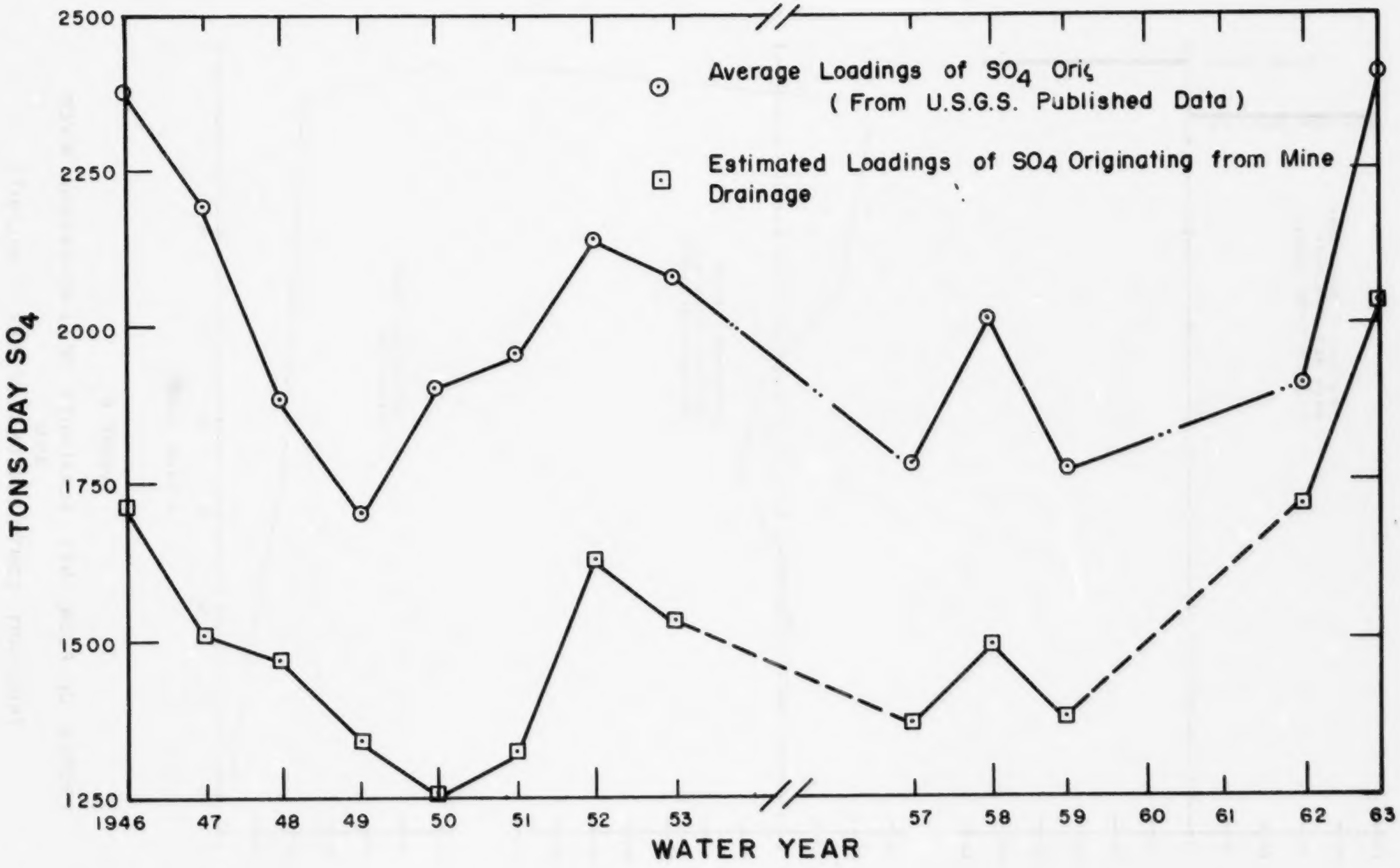


Figure 5. Average loads of total sulfate and sulfate considered to originate from coal mine drainage carried by the Susquehanna River at Danville, Pennsylvania.

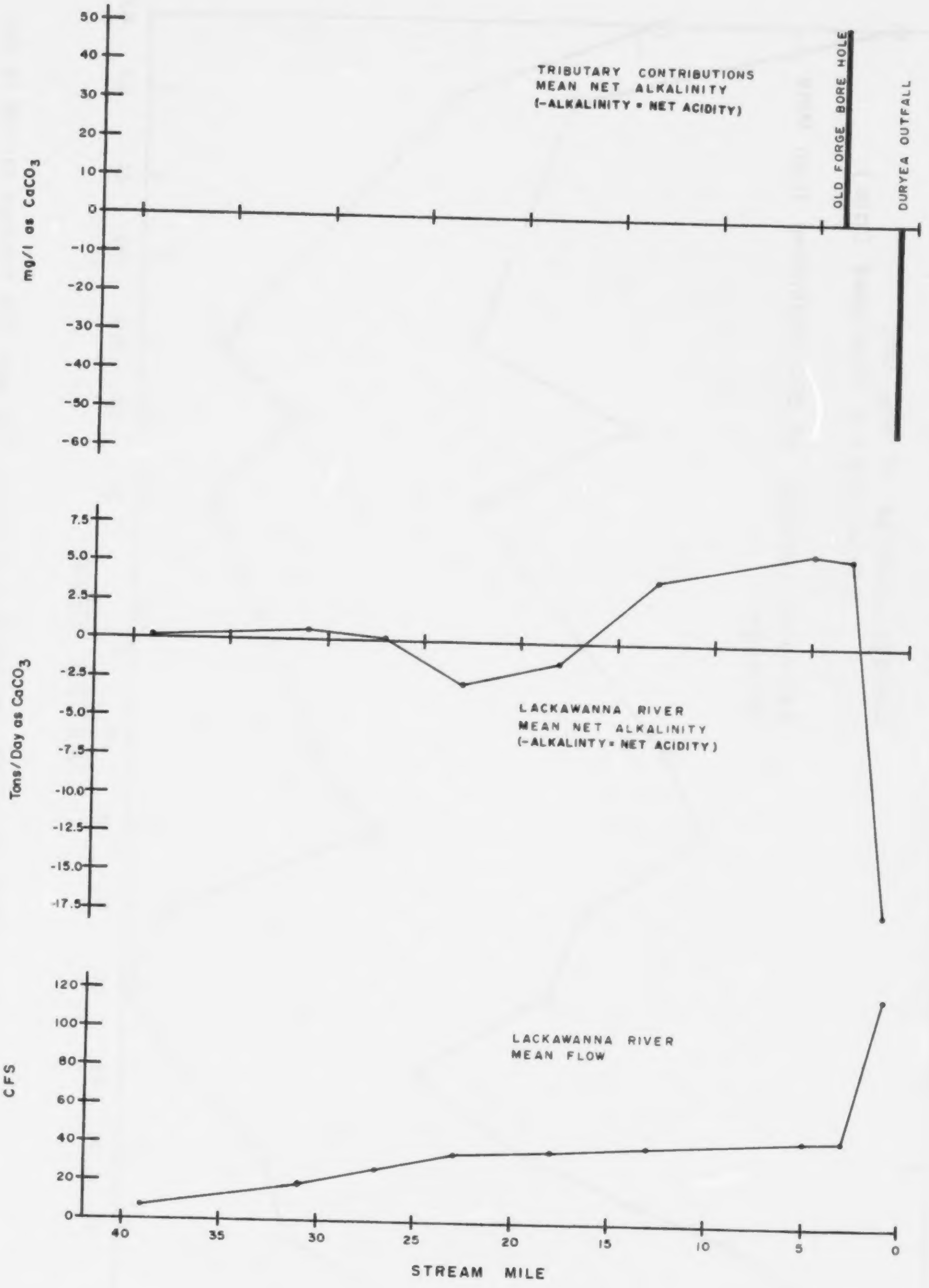


FIGURE 6

PROFILE OF FLOW, NET ALKALINITY OF LACKAWANNA RIVER
AND
TRIBUTARY CONTRIBUTIONS OF NET ALKALINITY

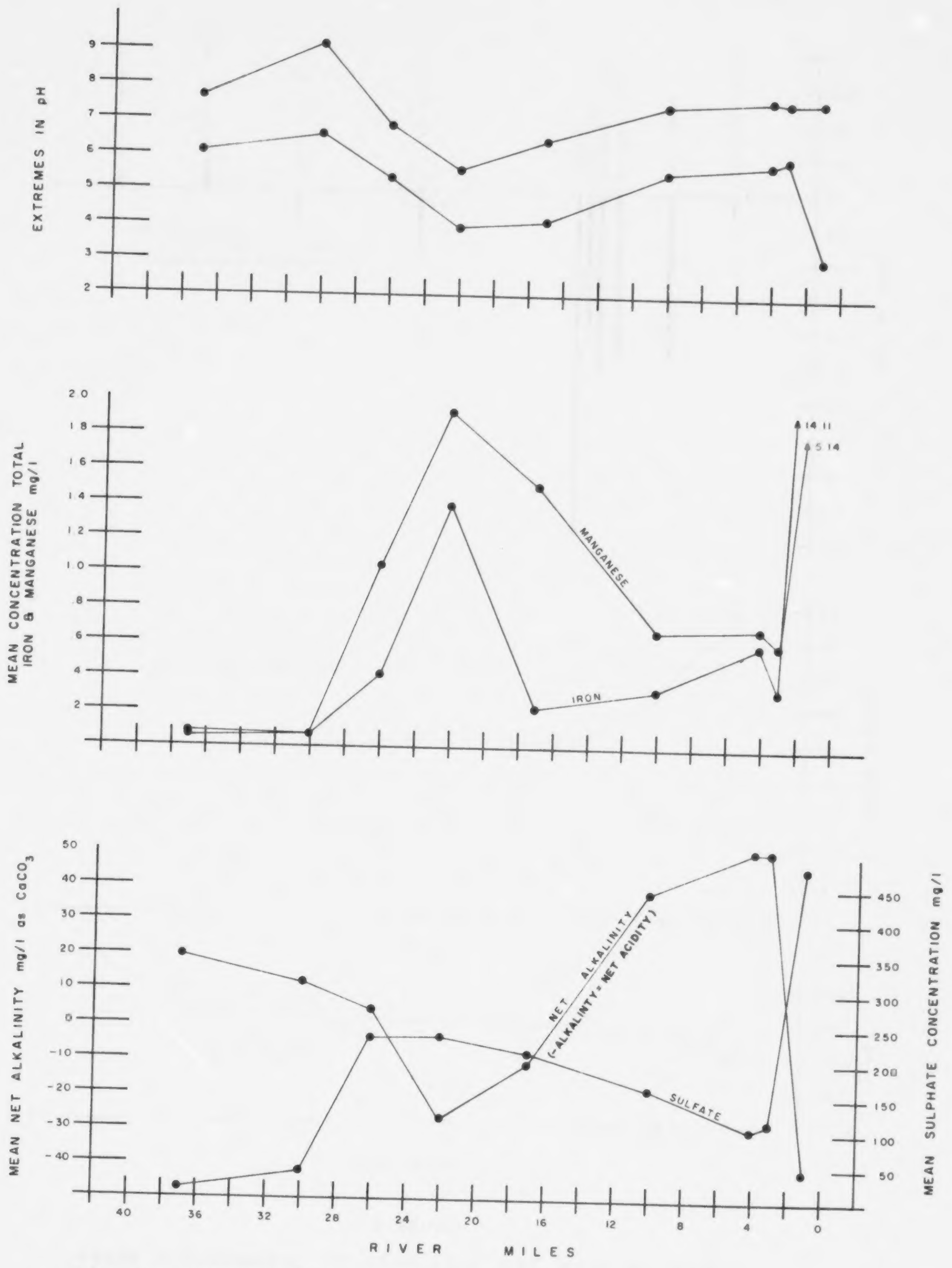


FIGURE 7 PROFILE OF pH, MANGANESE, IRON & SULFATE CONCENTRATION AND NET ALKALINITY

LACKAWANNA RIVER

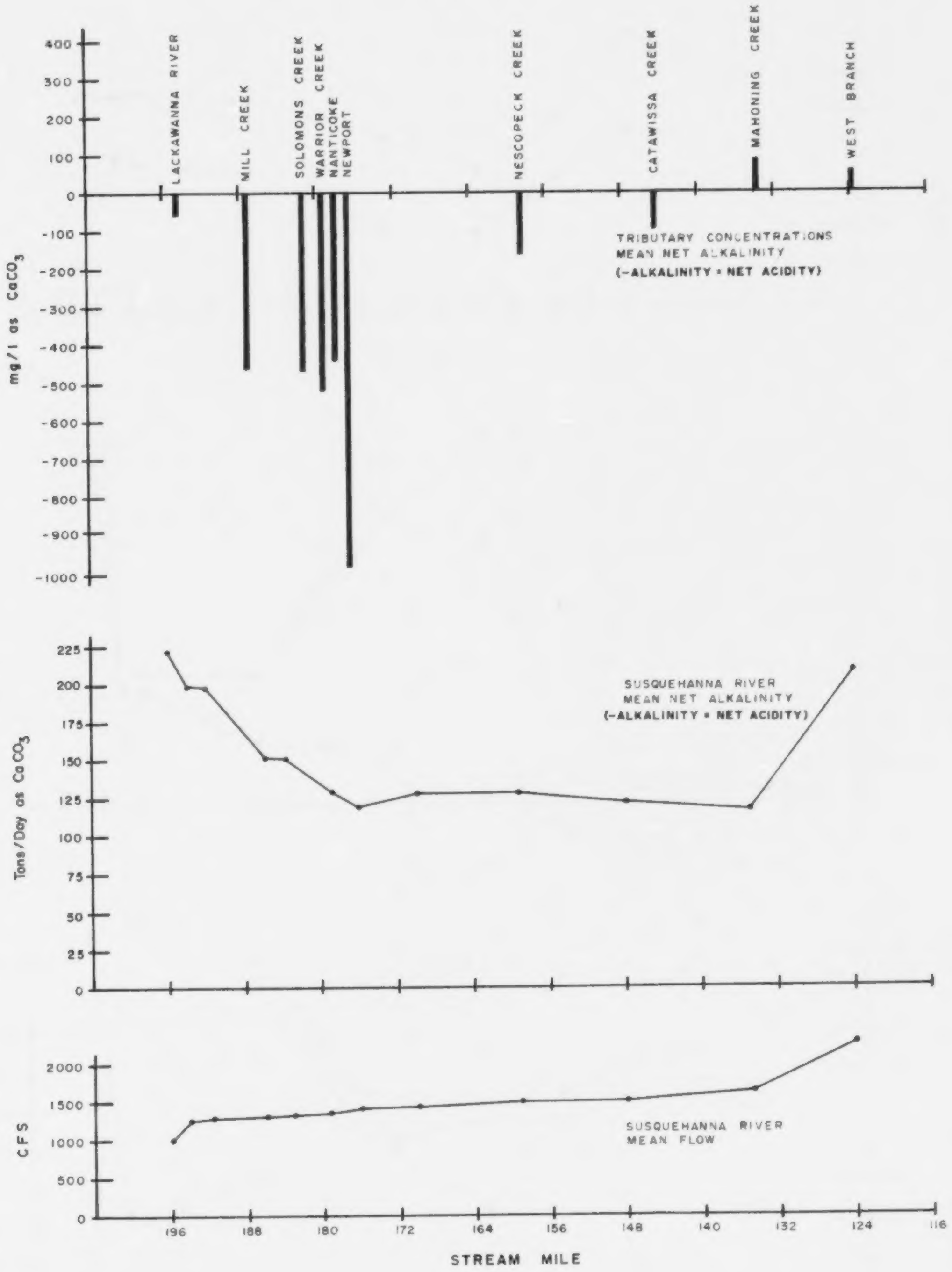


FIGURE 8

PROFILE OF FLOW, NET ALKALINITY OF SUSQUEHANNA RIVER
AND
TRIBUTARY CONTRIBUTIONS OF NET ALKALINITY

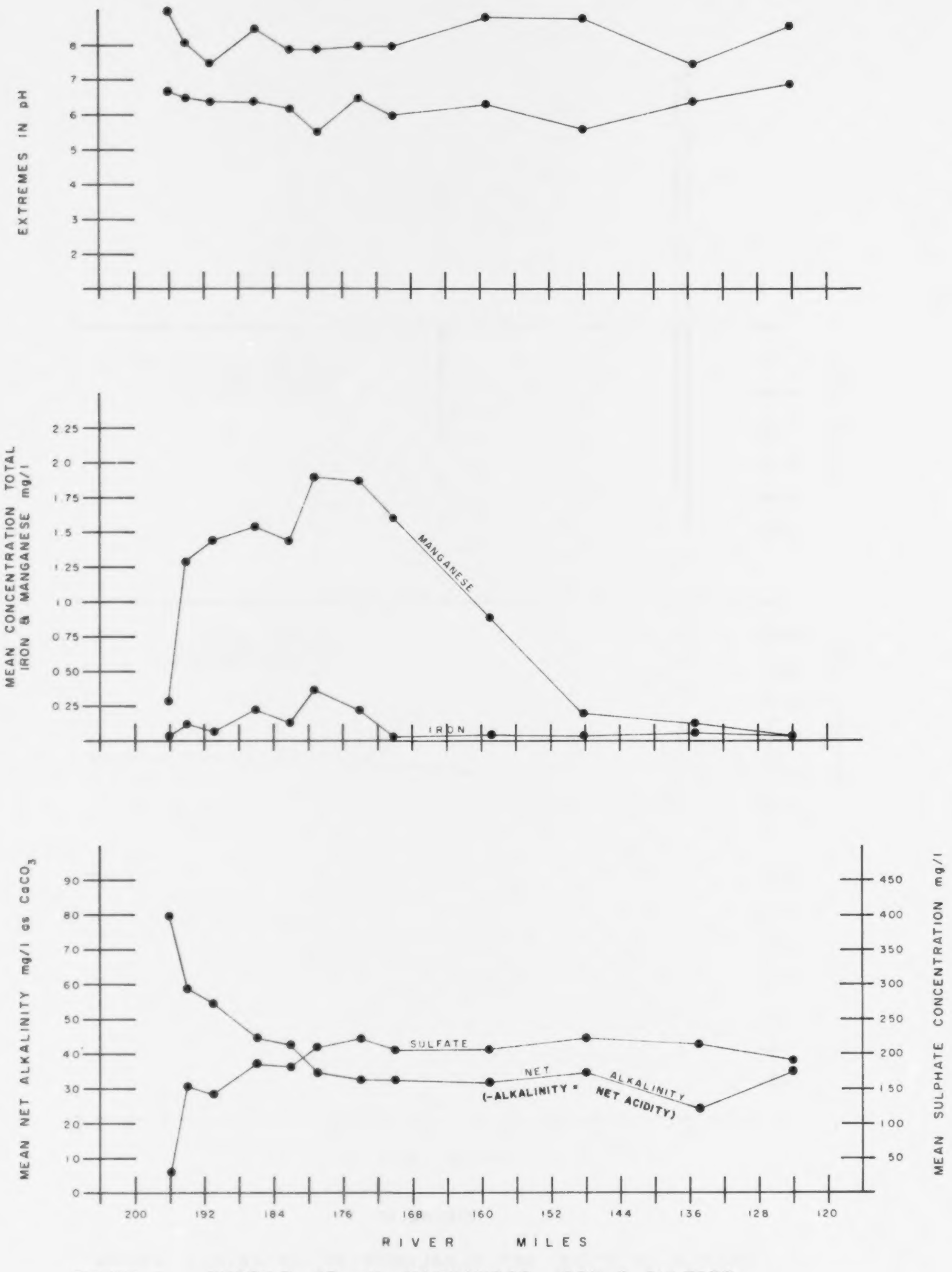


FIGURE 9 PROFILE OF pH, MANGANESE, IRON & SULFATE CONCENTRATION AND NET ALKALINITY

SUSQUEHANNA RIVER

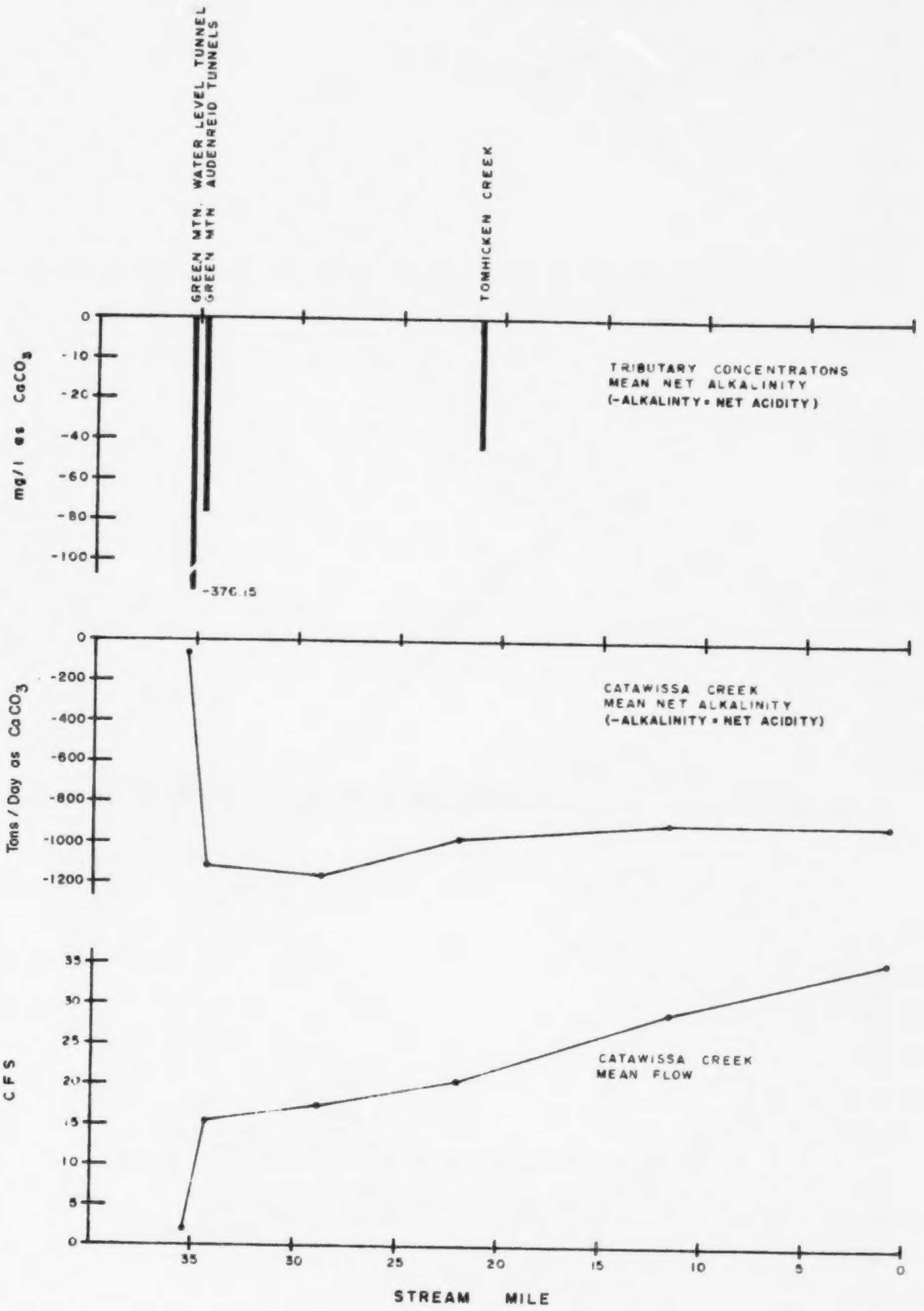


FIGURE 10

PROFILE OF FLOW, NET ALKALINITY OF CATAWISSA CREEK
AND
TRIBUTARY CONTRIBUTIONS OF NET ALKALINITY

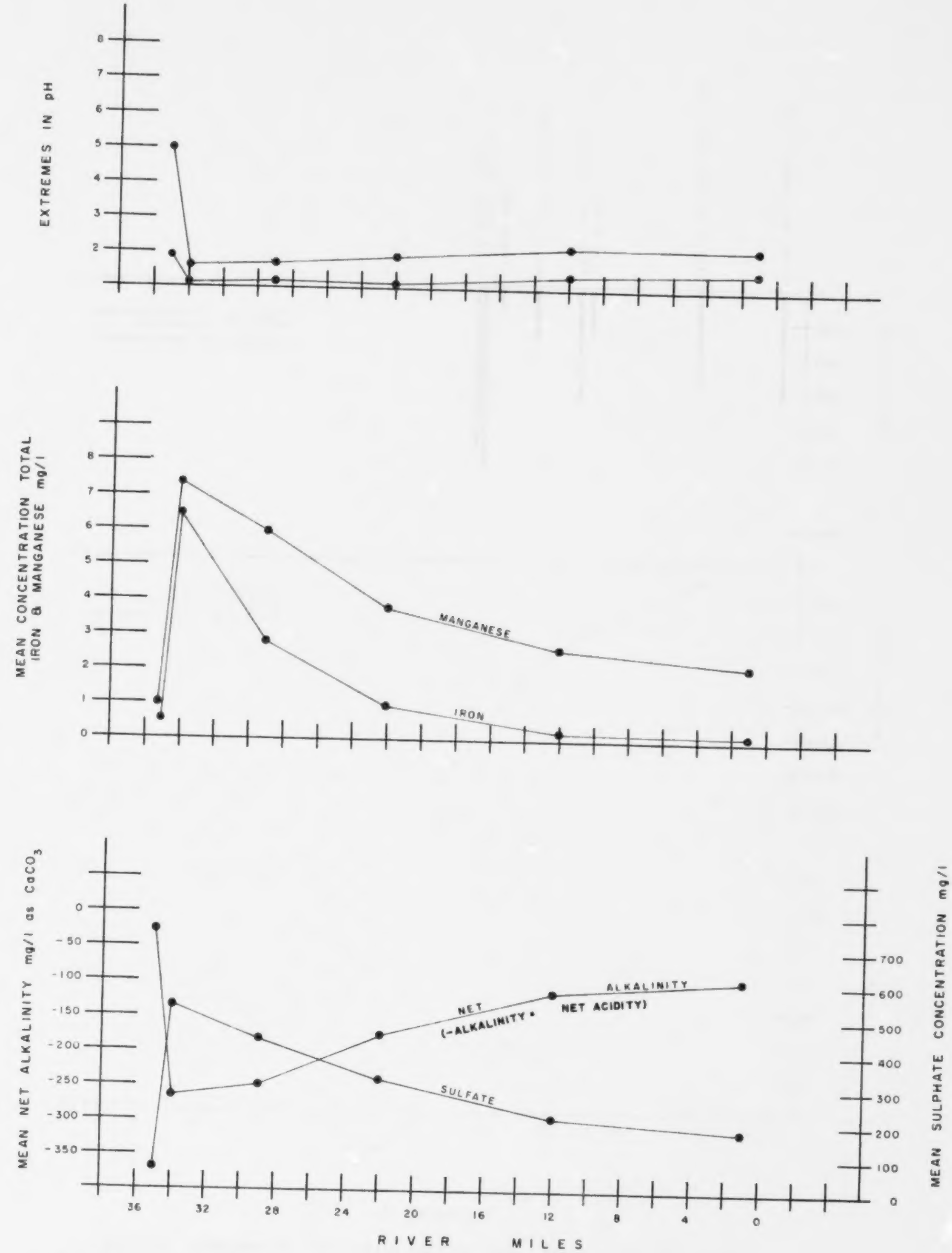


FIGURE II PROFILE OF pH, MANGANESE, IRON & SULFATE CONCENTRATION AND NET ALKALINITY

CATAWISSA CREEK

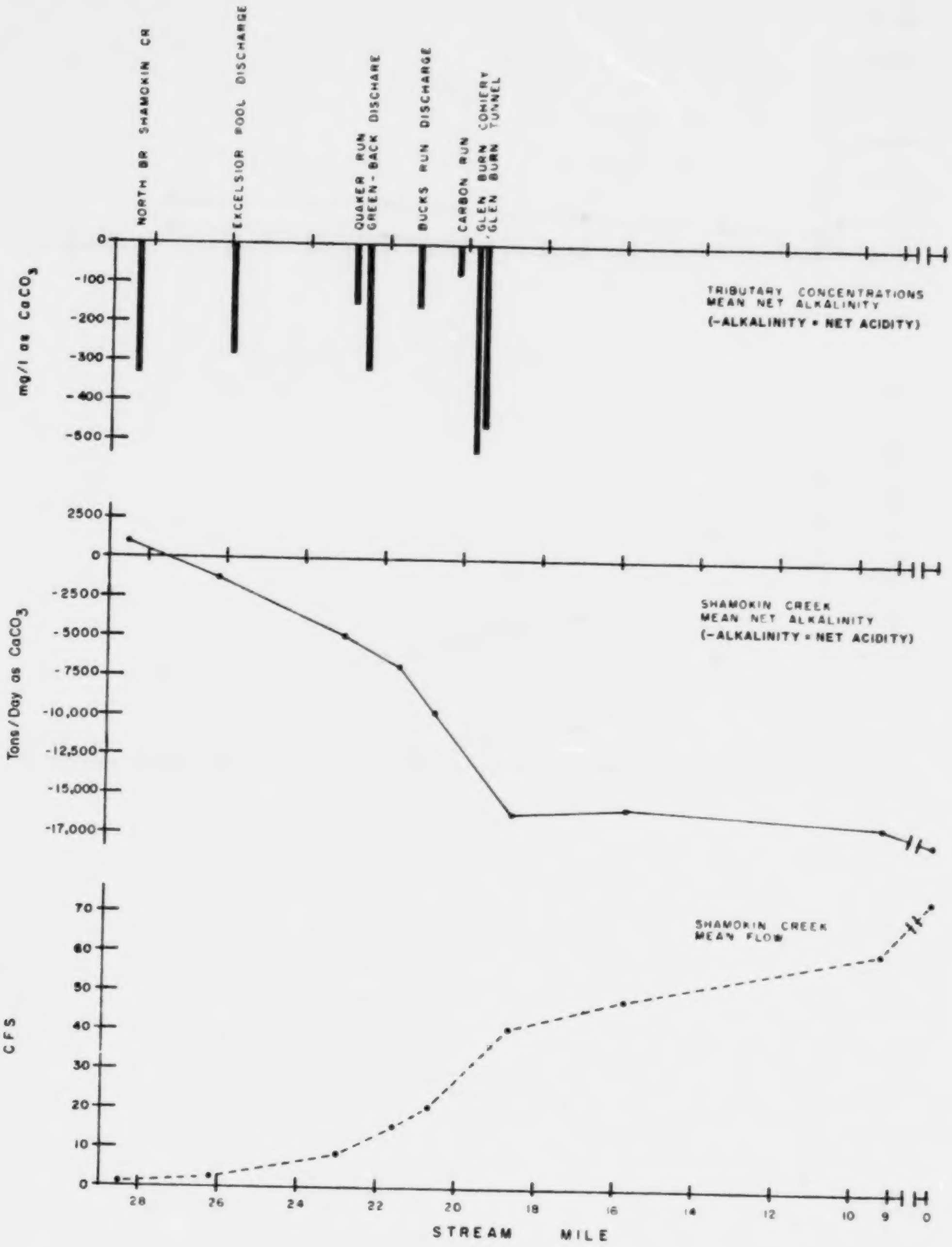


FIGURE 12

PROFILE OF FLOW, NET ALKALINITY OF SHAMOKIN CREEK
AND
TRIBUTARY CONTRIBUTIONS OF NET ALKALINITY

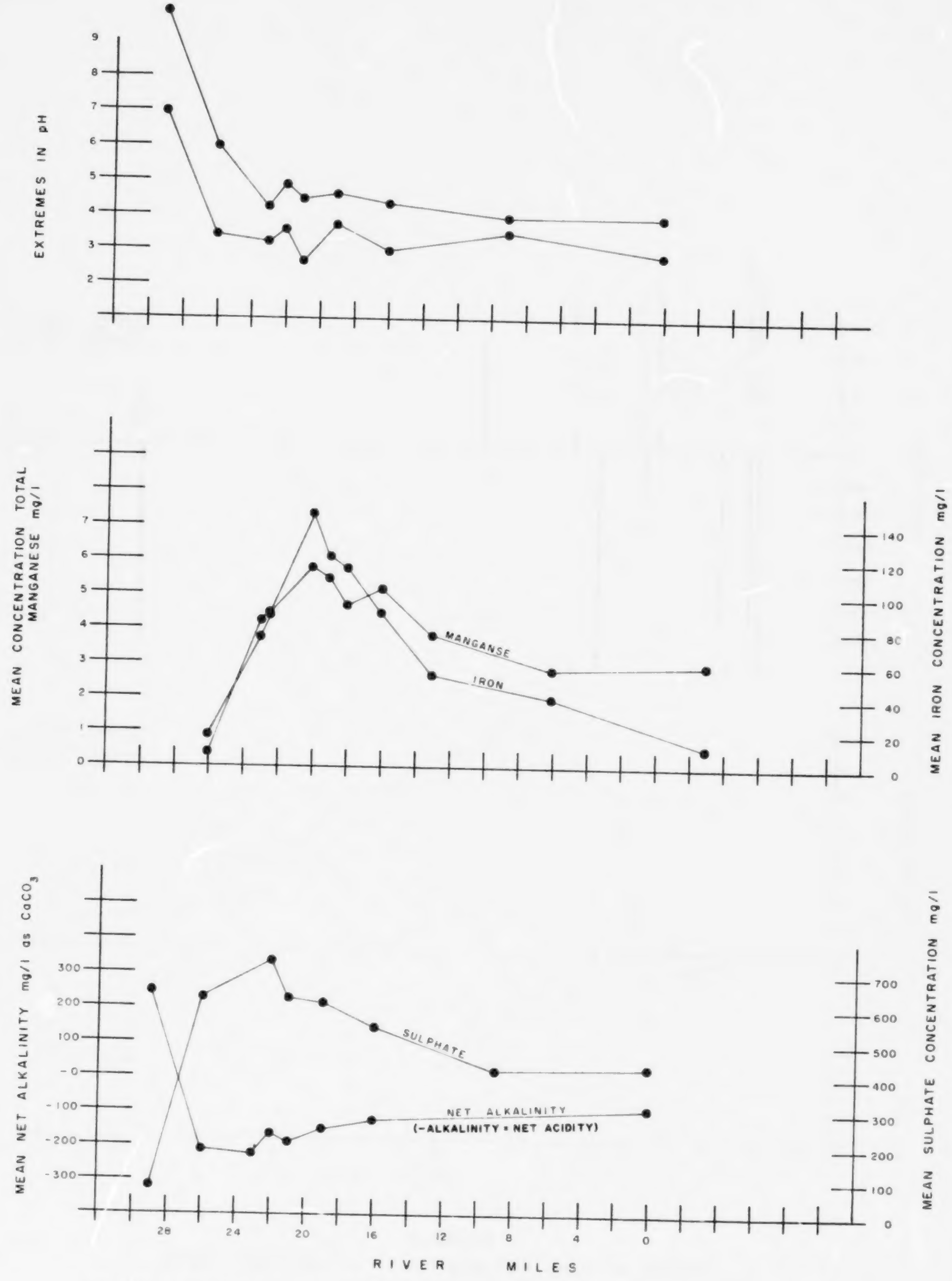


FIGURE 13 PROFILE OF pH, MANGANESE, IRON & SULFATE CONCENTRATION AND NET ALKALINITY

SHAMOKIN CREEK

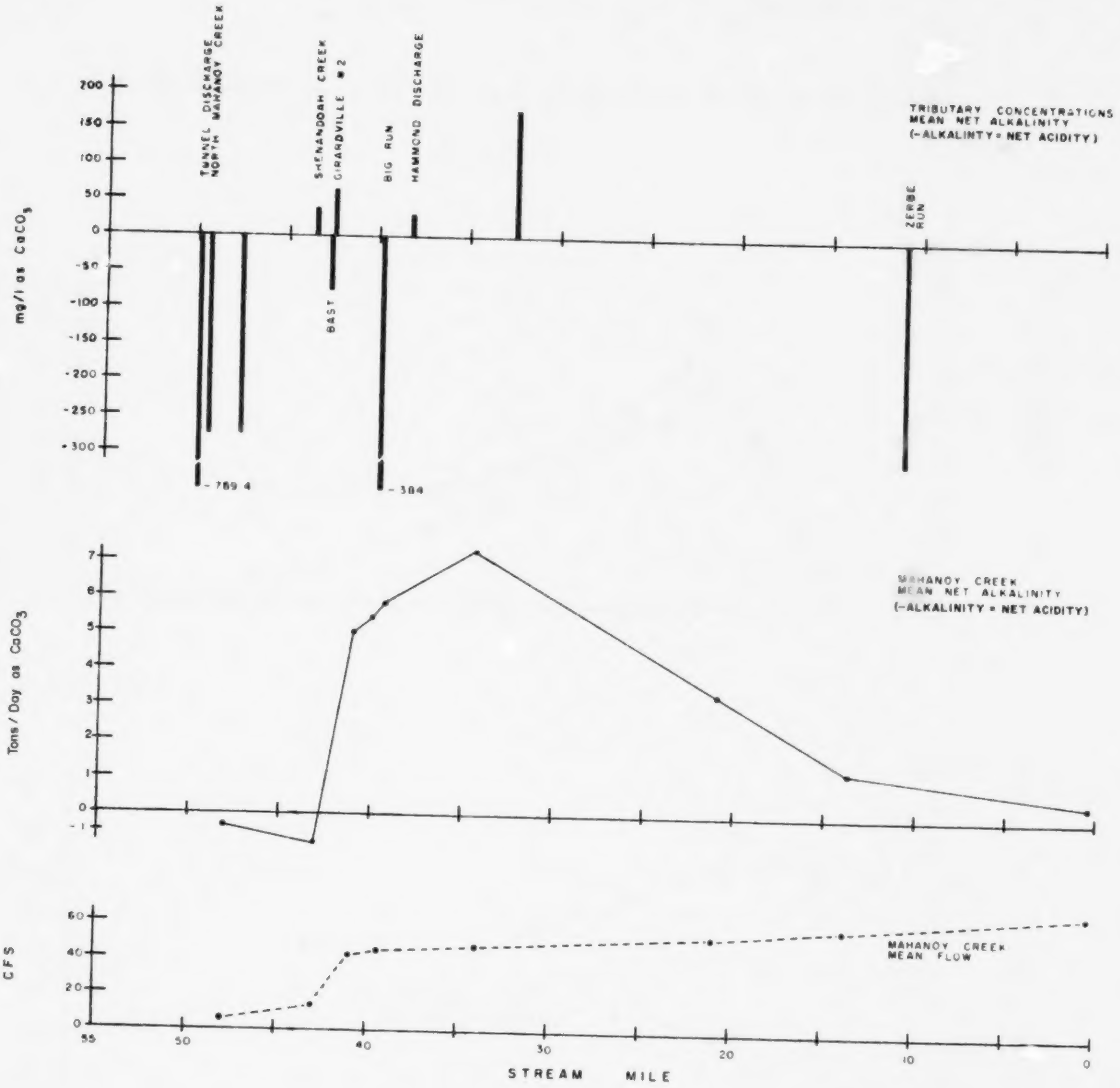


FIGURE 14

PROFILE OF FLOW, NET ALKALINITY OF MAHANOY CREEK
AND
TRIBUTARY CONTRIBUTIONS OF NET ALKALINITY

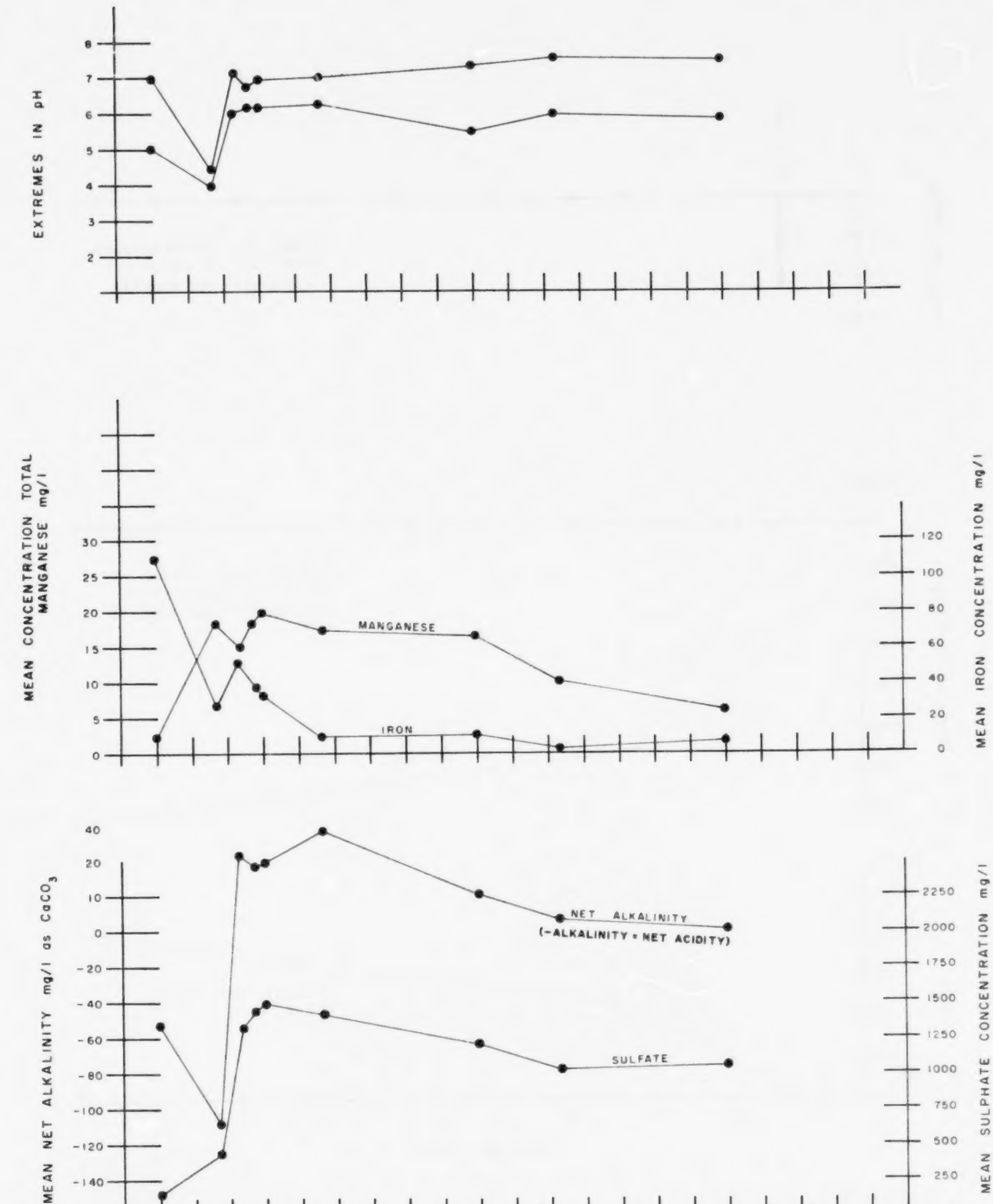


FIGURE 15 PROFILE OF pH, MANGANESE, IRON & SULFATE CONCENTRATION AND NET ALKALINITY

MAHANOY CREEK

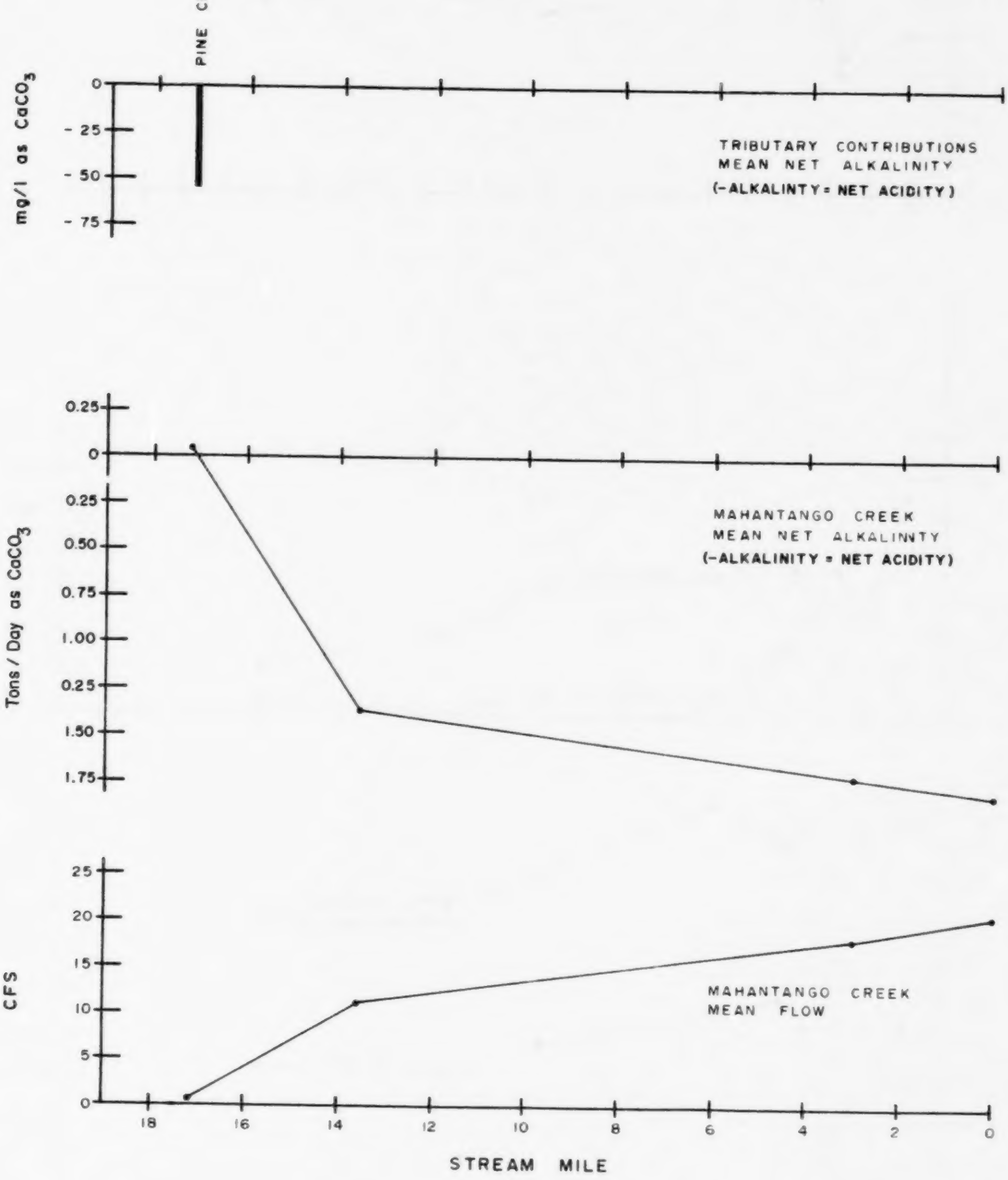


FIGURE 16

PROFILE OF FLOW, NET ALKALINITY OF MAHANTANGO CREEK
AND
TRIBUTARY CONTRIBUTIONS OF NET ALKALINITY

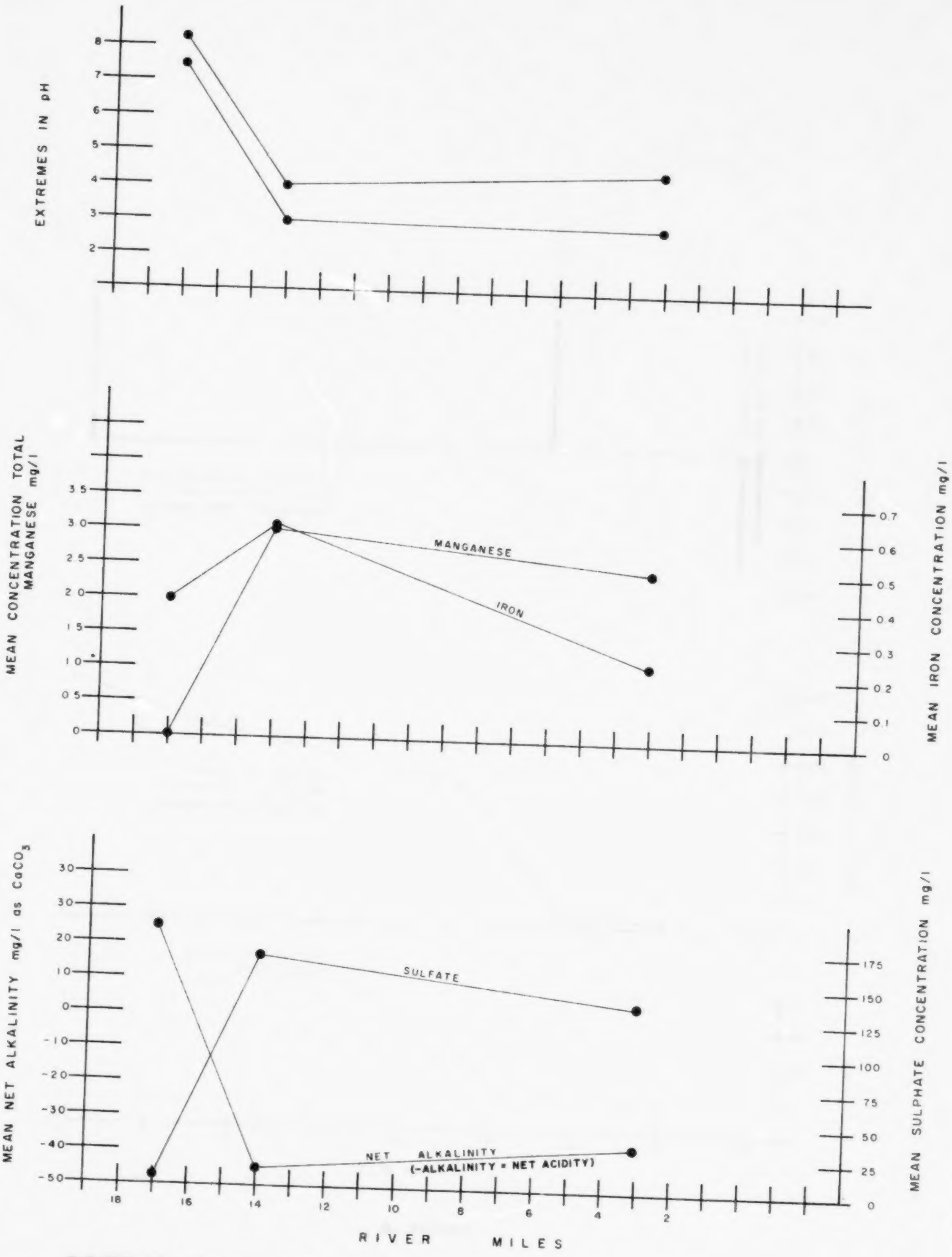


FIGURE 17 PROFILE OF pH, MANGANESE, IRON & SULFATE CONCENTRATION AND NET ALKALINITY

MAHANTANGO CREEK

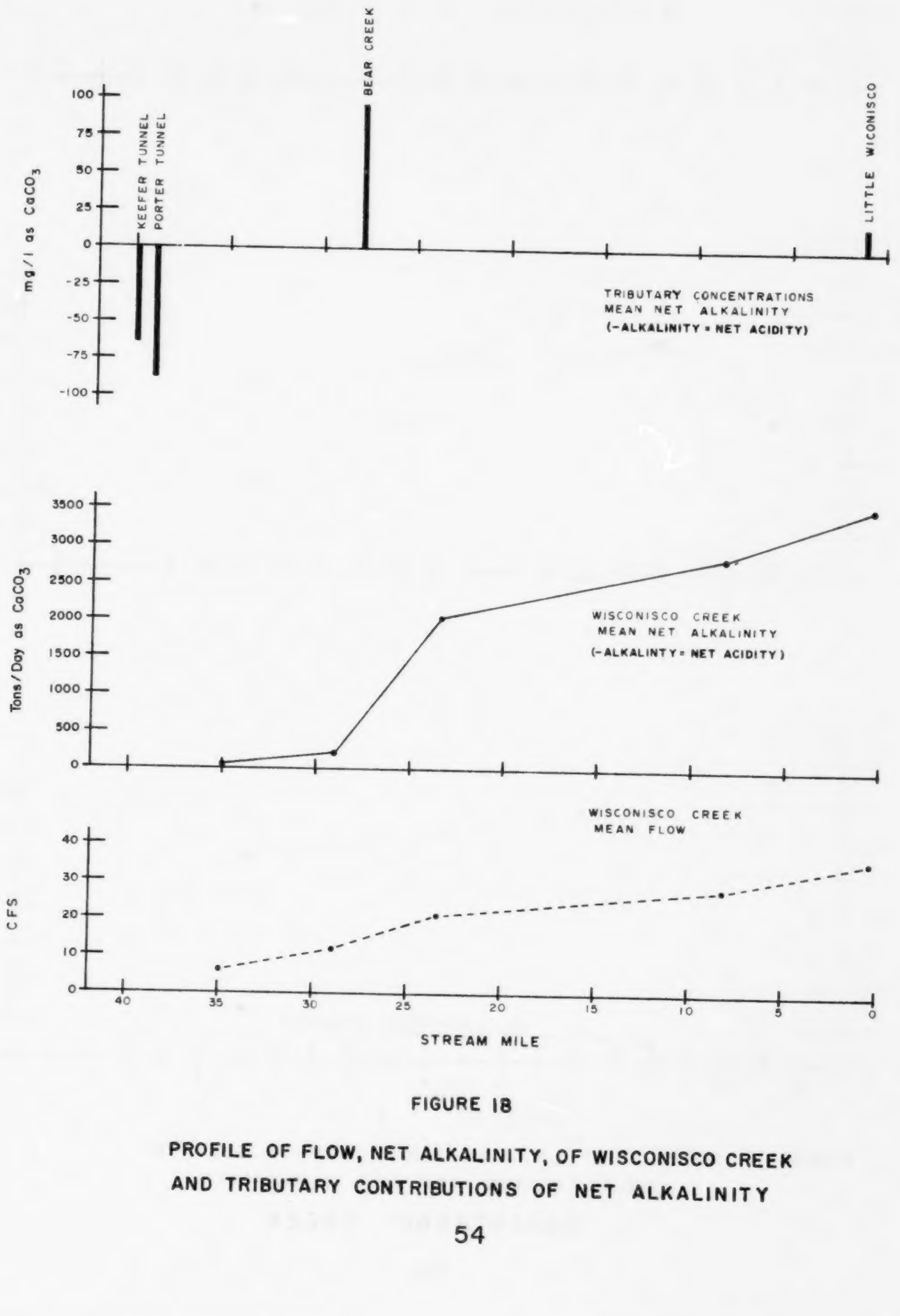


FIGURE 18

PROFILE OF FLOW, NET ALKALINITY, OF WISCONISCO CREEK AND TRIBUTARY CONTRIBUTIONS OF NET ALKALINITY

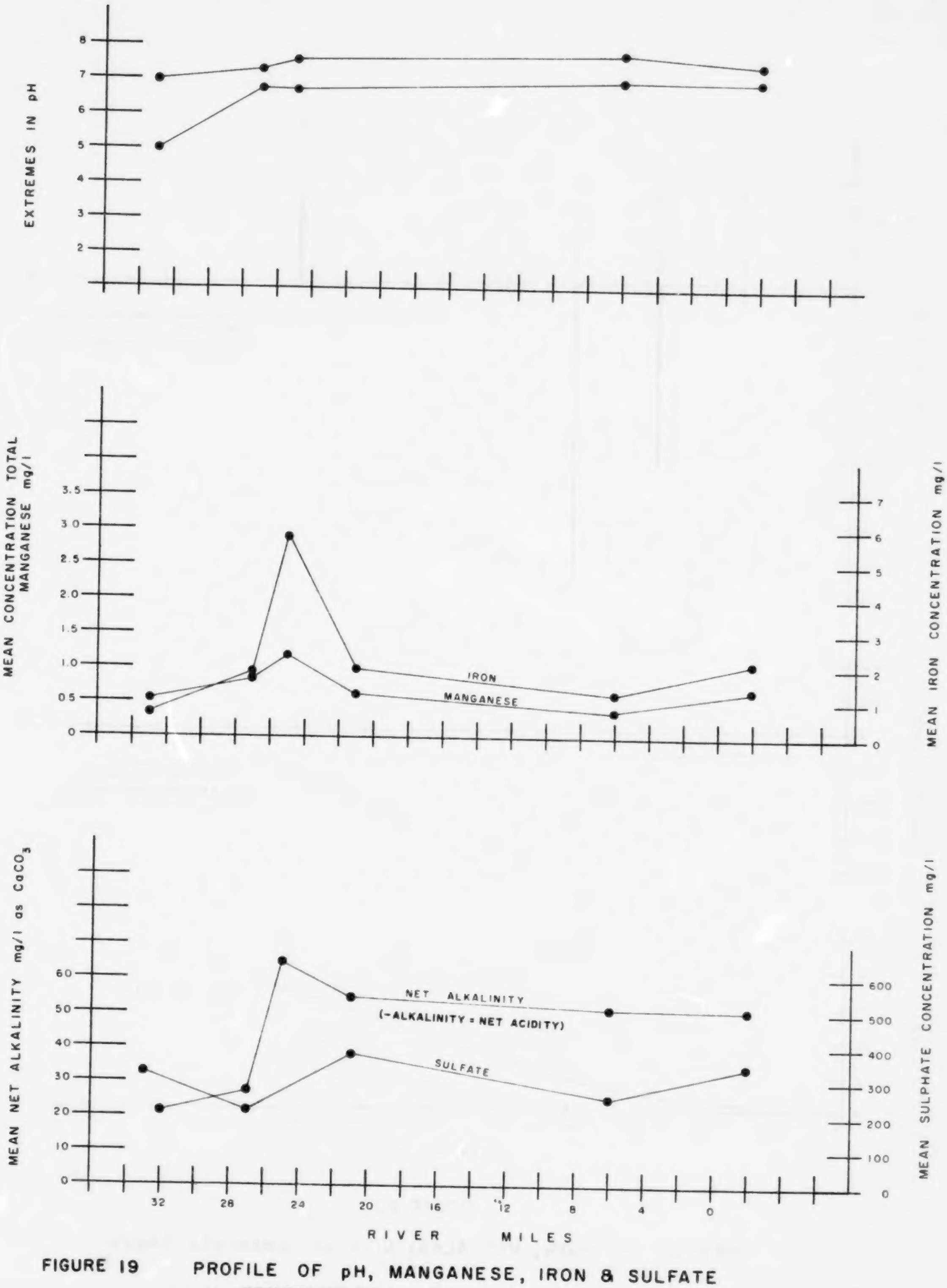


FIGURE 19 PROFILE OF pH, MANGANESE, IRON & SULFATE CONCENTRATION AND NET ALKALINITY

WICONISCO CREEK

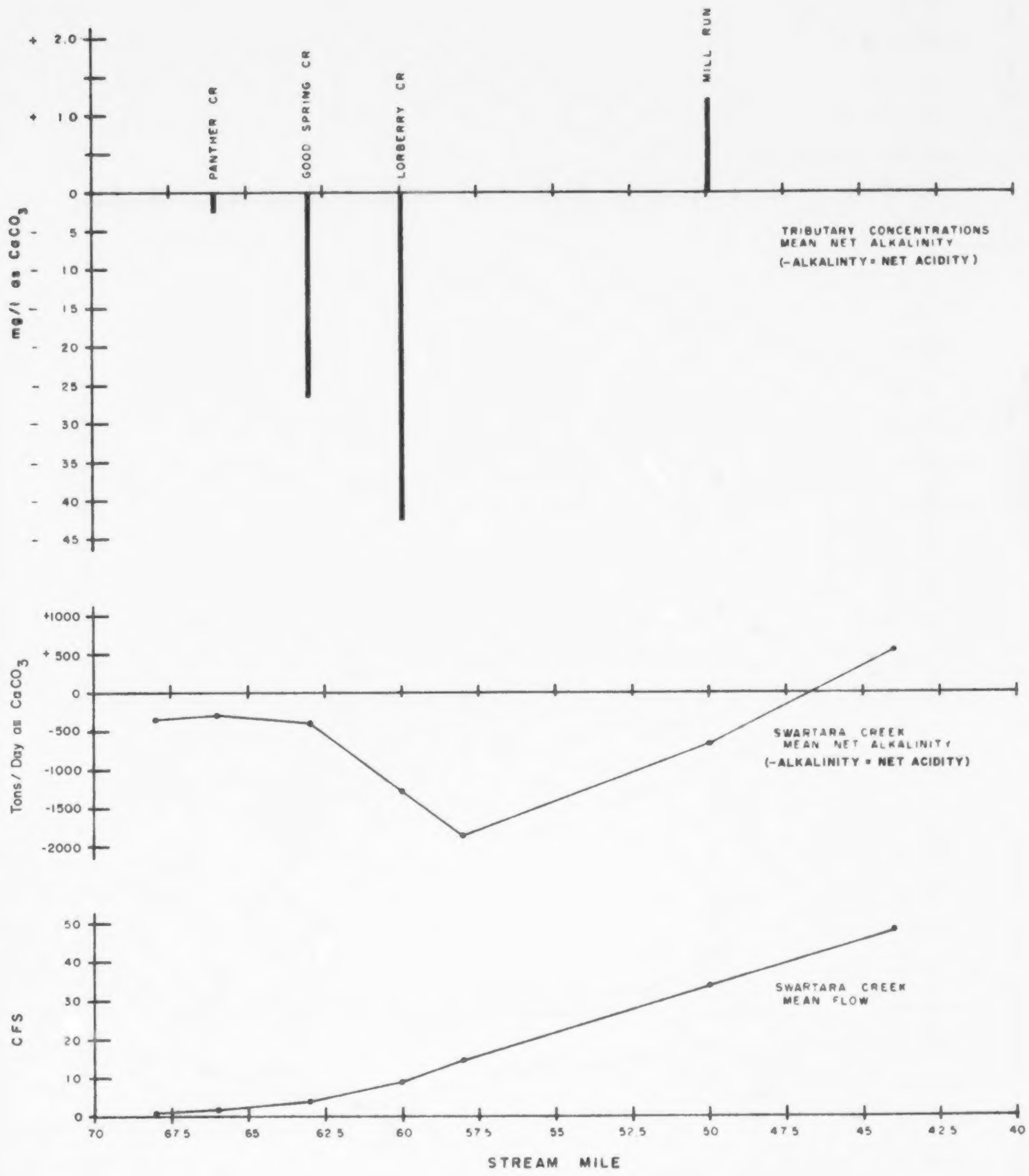


FIGURE 20

PROFILE OF FLOW, NET ALKALINITY OF SWARTARA CREEK
AND
TRIBUTARY CONTRIBUTIONS OF NET ALKALINITY

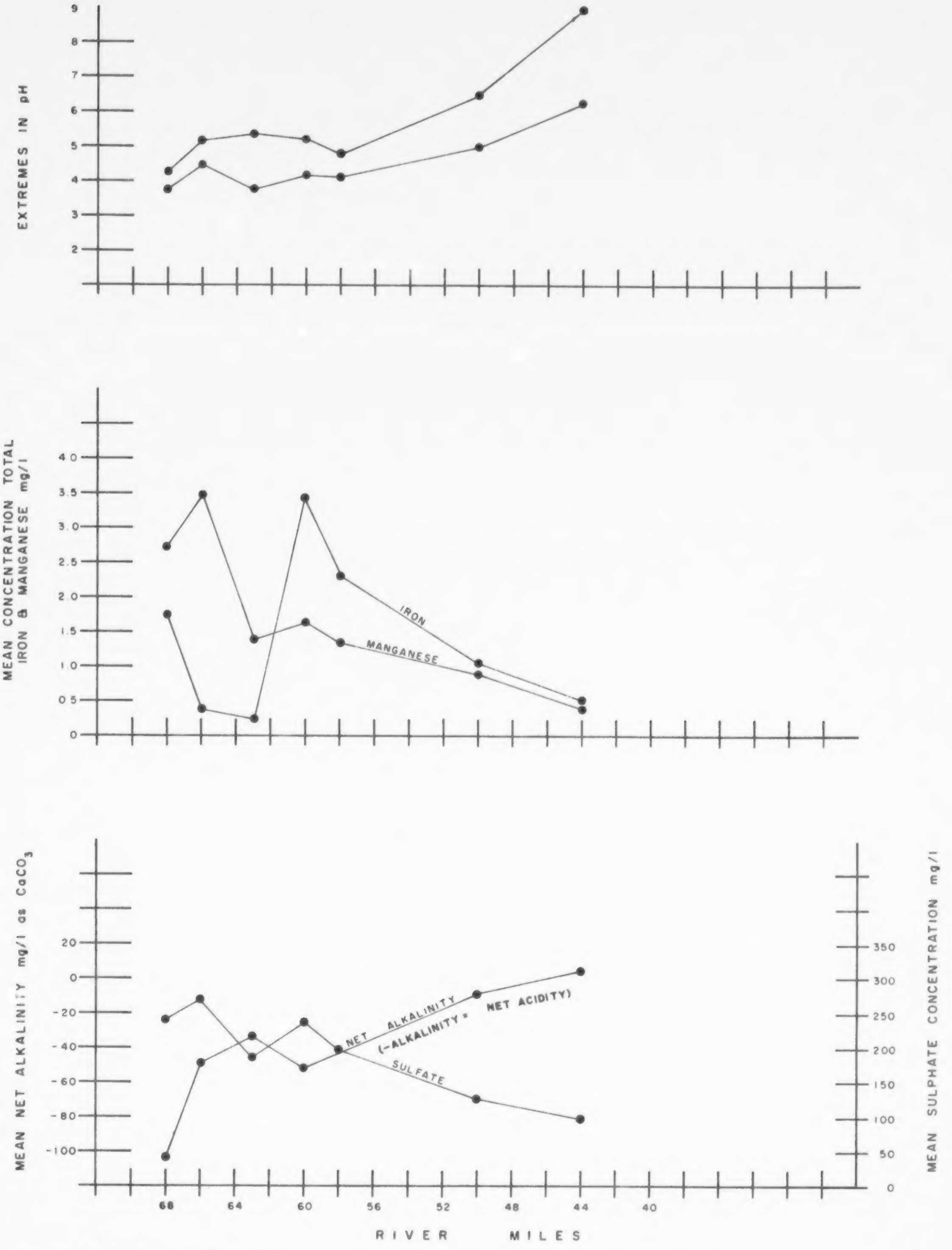


FIGURE 21 PROFILE OF pH, MANGANESE, IRON & SULFATE CONCENTRATION AND NET ALKALINITY

SWATARA CREEK

Tioga River Basin

Description

The Tioga River originates in western Bradford County, Pennsylvania. The stream is 58 miles long, 45 miles of which are in Pennsylvania. It flows in a southwesterly direction into Tioga County near Blossburg, Pennsylvania, and thence in a northerly direction to join the Chemung River in New York State. Figure 22 shows the portion of the Susquehanna River basin, which includes the Tioga River basin.

Located within the Allegheny Plateau physiographic province, the Tioga basin is characterized by broad valleys and steep, rounded hills. Shale, sandstone, and coal are the dominant rock types. Most of the stream channels contain deposits of glacially derived boulders and gravel.

Coal deposits in the basin are located in the extreme headwaters and are contained in a canoe shaped synclinal basin. Of the four minable beds contained in the basin, three have been or are being mined.

Mining activity began in the Tioga basin in the 1840's reaching a maximum of approximately 1.4 million tons in 1886. Production has since declined to a level of approximately 0.4 million tons in 1964. Great emphasis is placed on surface mining. Approximately 80 percent of the coal is produced by this method. Projections of production for the Tioga River basin are shown in the following table:

Projected Bituminous Coal Production (Thousand Tons)

1970	1985	2020
360	460	660

Reserves of coal have been estimated at a total of 41 million short tons, with approximately 16 million short tons considered recoverable (Wessell and others, 1966).

Mine Drainage Sources and Their Effect on Stream Quality

There are only 22 major coal mine drainage sources in the Tioga River basin and 4,500 acres of unreclaimed strip-mined land. All of the drainage originates from inactive mines. Fifteen underground sources contribute 11.8 tons/day of acidity and seven surface sources contribute 1.2 tons/day of acidity.

Preceding page blank

A. Tioga River

The quality of the Tioga River above its confluence with Morris Run is not significantly affected by mine drainage. The stream is, in fact, classified as a trout stream by the Pennsylvania Fish Commission. Below this point, however, for a distance of more than 25 miles, the stream is rendered acid by mine drainage contributed by Morris Run, Coal Creek, Johnson Creek and Bear Creek (Figure 23). Downstream tributaries have weak alkalinity common to this area, but succeed in neutralizing the acid load downstream from the Cowanesque River. Biological studies indicate mine drainage inhibition of aquatic life downstream to the confluence with the Canisteo River, an additional nine miles.

The Corps of Engineers is planning a multipurpose dam and reservoir at the confluence of Crooked Creek and the Tioga River. The dam will impound both streams in separate impoundments. Mine drainage influence on the quality of the Tioga River impoundment will limit water uses. The mean net acidity at the dam site was 100 mg/l during the survey. Iron and manganese concentrations were 2.0 and 3.7 mg/l, respectively. The pH ranged from 3.7 to 4.1.

1. Johnson Creek

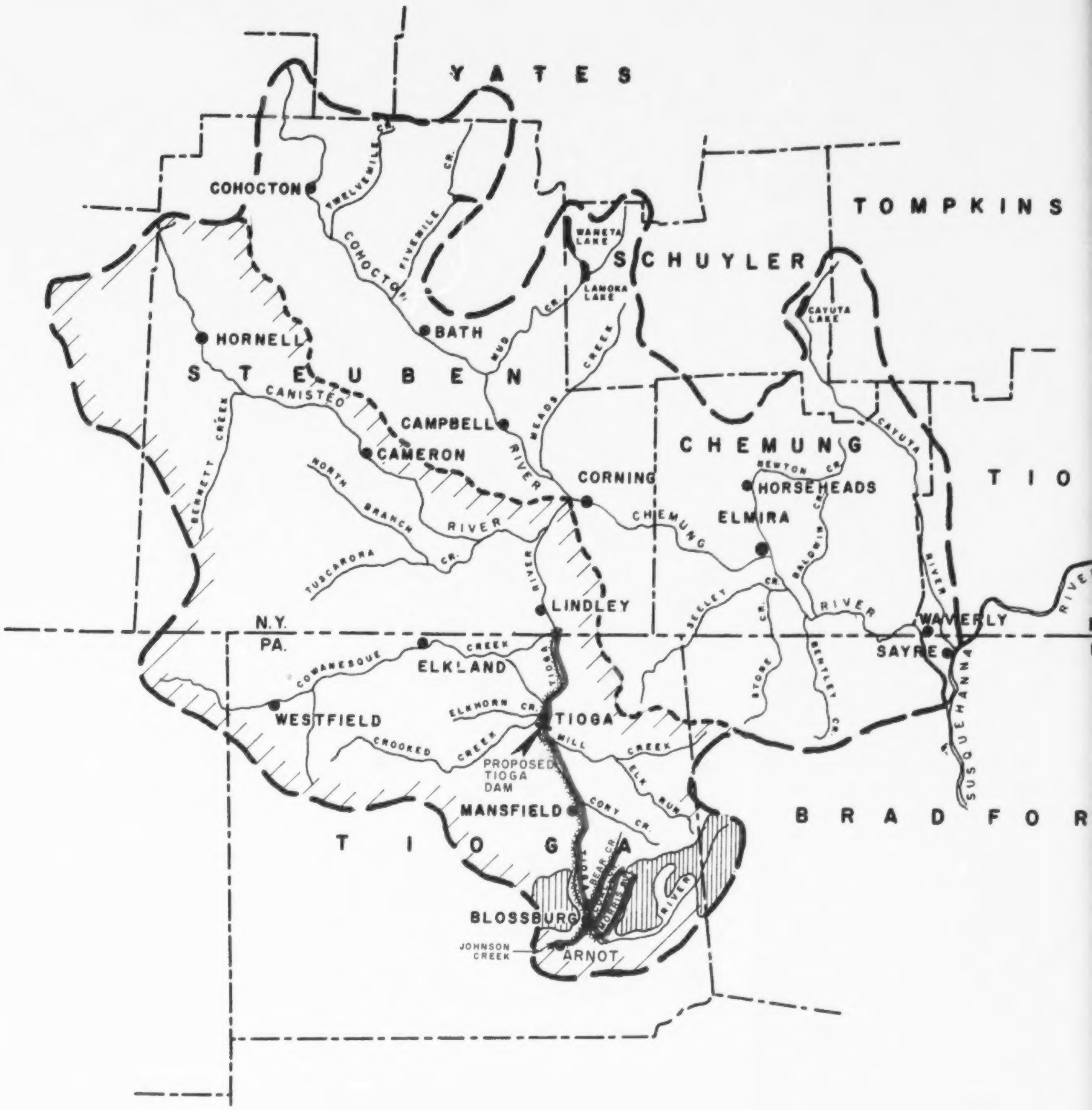
Although Johnson Creek contributed a weak alkaline loading to the Tioga River, it does receive mine drainage from abandoned surface and underground mines near the Village of Arnot, as shown in Figure 22, mine drainage contributed in the Arnot area overcomes the stream's alkalinity for a short distance. Mine drainage indicator concentrations are low in Johnson Creek downstream from Arnot. Two discharges with a total net acid loading of 0.2 tons/day were determined to be the major mine drainage contributors in the watershed.

2. Morris Run, Coal Creek, and Bear Creek

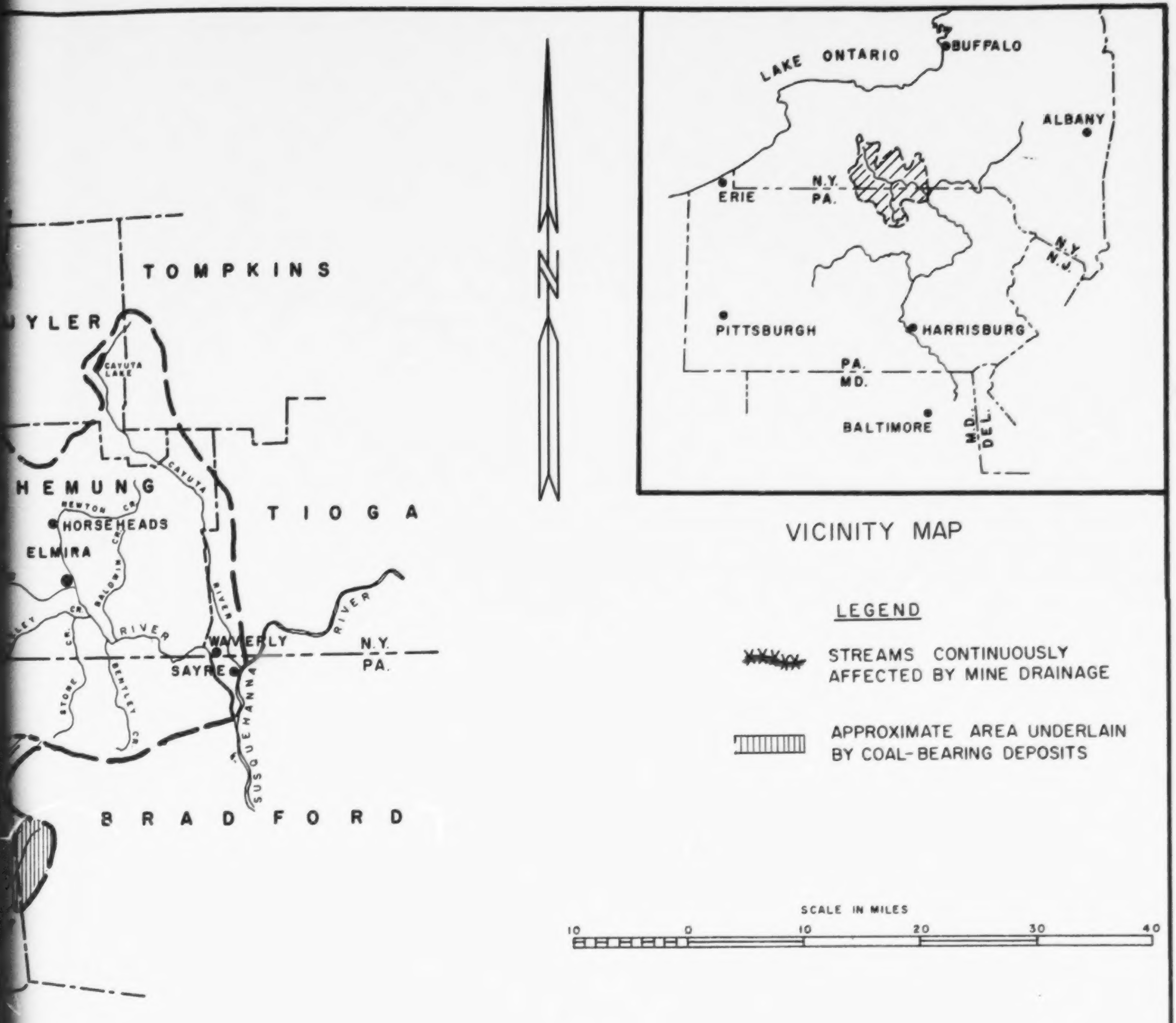
Although Morris Run, Coal Creek, and Bear Creek constitute individual sources of mine drainage to the Tioga River, they overlie a common coal deposit. Underground and surface mining has diverted surface and ground water from watershed to watershed. The three watersheds will, therefore, be discussed as a single mine drainage source to the Tioga River.

As illustrated in Figure 23, the total acidity discharged from the three streams exhausted the Tioga River's rather weak alkaline reserve and produced an acid residual of 7.75 tons/day acidity downstream from Bear Creek during the survey period. The mean acidity concentration downstream from Bear Creek was 180 mg/l. Mean iron and manganese concentrations were 16 and 4.9 mg/l, respectively. Other mine drainage indicators were proportionately high.

Each of the three streams is acid from source to mouth, as are most of their tributaries. The quality of the three streams is essentially uniform from source to mouth. All have acidity concentrations in the 500 to 1,000 mg/l range, iron concentrations in the 20 to 100 mg/l range, and manganese concentrations in the 20 to 50 mg/l range. Morris Run receives mine drainage from two major sources and approximately 20 less significant sources. Most of the drainage originates in abandoned deep mines; however, their flow is undoubtedly influenced by contributions from strip mines, some of which lie in the Coal Creek and Bear Creek watersheds.


YATES
TOMPKINS
SCHUYLER
STEUBEN
CHEMUNG
TIO
TIOGA
BRAD FOR
COHOCTON
TWELVEMILE CR.
FIVEMILE CR.
CR.
COHOCTON
WANETA LAKE
LAMOKA LAKE
CAYUTA LAKE
HORNELL
BATH
MUD CR.
CREEK
CANISTEO
CAMPBELL
CAMERON
MEADS
RIVER
NORTH BRANCH RIVER
BENNETT CREEK
TUSCARORA CR.
CORNING
NEWTON CR.
HORSEHEADS
ELMIRA
CHEMUNG
BALDWIN CR.
CAYUTA
RIVER
RIVER
LINDLEY
SEELEY CR.
RIVER
WAVERLY
SAYRE
N.Y.
PA.
COWANESQUE CREEK
ELKLAND
STONE CR.
BENTLEY CR.
SUSQUEHANNA
WESTFIELD
ELKHORN CR.
TIOGA
TIOGA
CROOKED CREEK
MILL CREEK
PROPOSED TIOGA DAM
ELK RUN
MANSFIELD
CORY CR.
BEAR CR.
MORRIS RUN
RIVER
BLOSSBURG
JOHNSON CREEK
ARNOT

A


TOMPKINS
YLER
CAYUTA LAKE
CAYUTA
HEMUNG
NEWTON CR.
HORSEHEADS
ELMIRA
BALDWIN CR.
CR.
RIVER
STONE CR.
BENTLEY CR.
WAVERLY
SAYRE
RIVER
SUSQUEHANNA
RIVER
N.Y.
PA.
TIOGA
BRADFORD
LAKE ONTARIO
BUFFALO
ALBANY
ERIE
N.Y.
PA.
N.Y.
N.J.
PITTSBURGH
HARRISBURG
PA.
MD.
BALTIMORE
MD.
DEL.
VICINITY MAP
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
SCALE IN MILES
10
0
10
20
30
40

APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 22

Preceding page blank

TIOGA RIVER BASIN

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

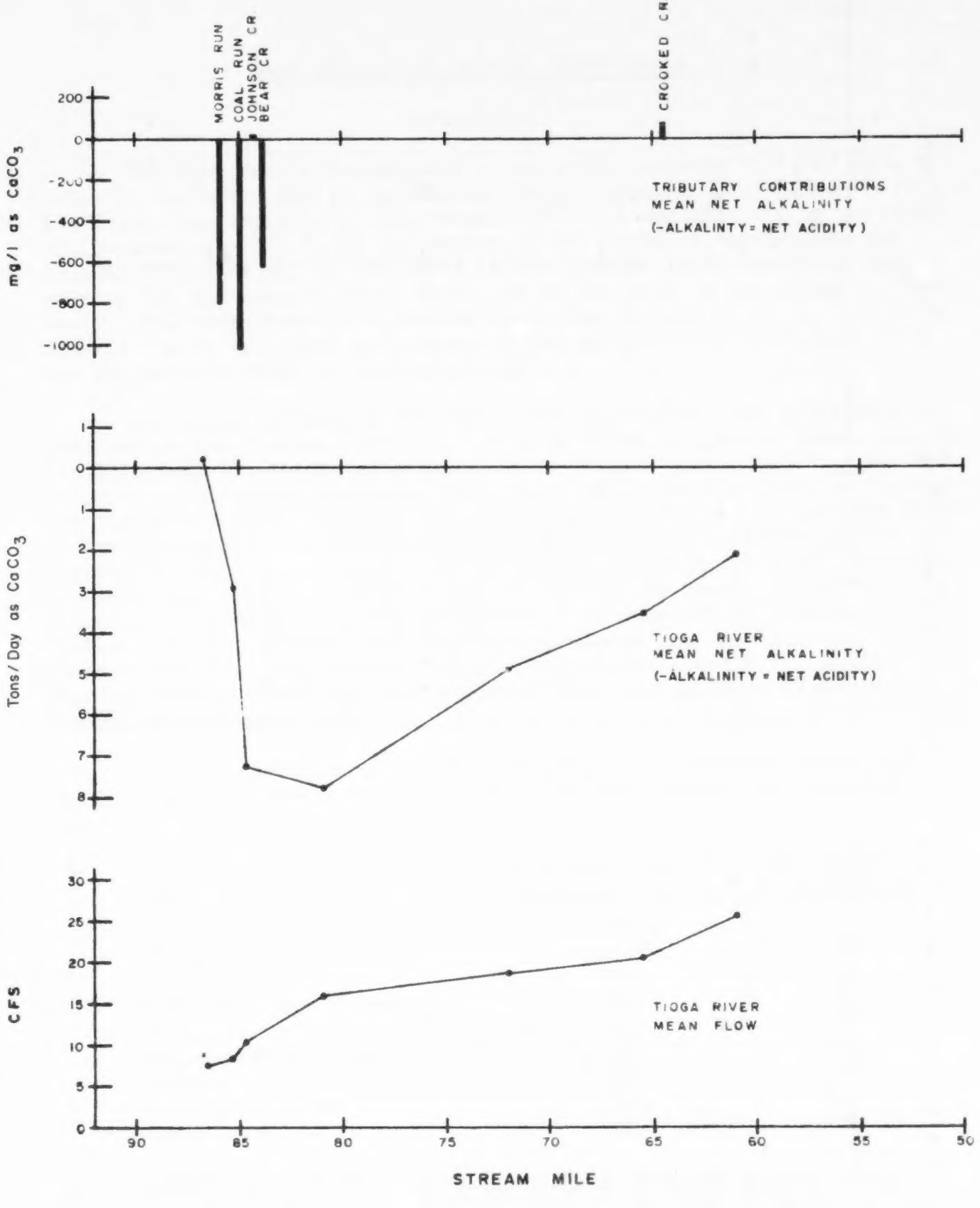


FIGURE 23

PROFILE OF FLOW, NET ALKALINITY OF TIOGA RIVER
AND
TRIBUTARY CONTRIBUTIONS OF NET ALKALINITY

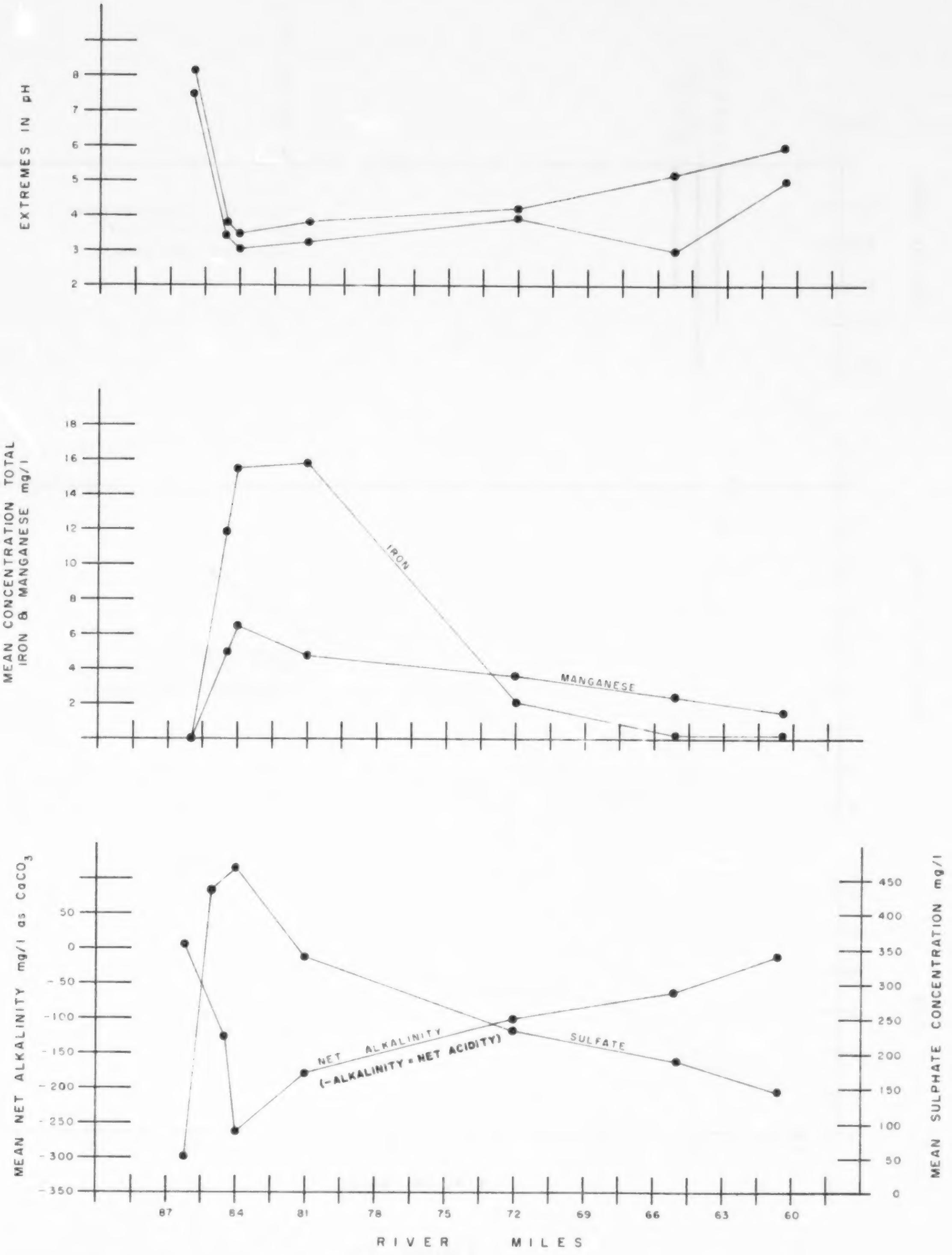


FIGURE 24 PROFILE OF pH, MANGANESE, IRON & SULFATE CONCENTRATION AND NET ALKALINITY

TIOGA RIVER

West Branch Susquehanna River Basin

Description

The West Branch Susquehanna River drains an area of 6,913 square miles in the west central portion of the Susquehanna River basin (Figure 25). The basin lies entirely within Pennsylvania and includes all or portions of 19 counties. The basin is bounded on the north by the Genesee and Chemung River basins, on the south by the Juniata River basin, on the east by the Susquehanna River basin and on the west by the Allegheny River basin. The West Branch Susquehanna River has its source in northwestern Cambria County and flows a distance of 240 miles to its confluence with the Susquehanna River at Northumberland.

The upper portion of the basin lies within the high tablelands of the Appalachian Plateau Province. At Lock Haven, the river breaks through the Allegheny Front, the escarpment which divides the Appalachian Plateau and Valley and Ridge Provinces, then flows approximately 70 miles through the Valley and Ridge Province to its confluence with the Susquehanna River. In the Appalchian Plateau Province, stream valleys are narrow and are flanked by high, steep hills. In the Valley and Ridge Province, valleys are generally broad and fertile and are bounded by rugged forested mountains. Moderate to steep gradients of streams in the Appalachian Plateau Province provide considerable turbulence and excellent mixing characteristics. The combination of low gradient and a wide, shallow channel configuration combine to produce poor mixing characteristics in the Valley and Ridge Province.

Major tributaries of the West Branch, their drainage areas and the mile point of their confluence with the main stream are tabulated below.

Name	Drainage Area (square miles)	Mile Point of Confluence
Loyalsock Creek	493	35
Lycoming Creek	276	41
Pine Creek	973	67
North Bald Eagle Creek	782	78
Kettle Creek	239	104
Sinnemahoning Creek	1,033	110
Moshannon Creek	286	136
Clearfield Creek	396	172
Chest Creek	132	205

Consolidated rocks that outcrop in the area are all of Paleozoic age and belong primarily to the Pennsylvanian and Mississippian Systems.

The Pennsylvanian age Conemaugh and Allegheny Formations contain the coal beds of economic significance.

It is estimated that approximately 4,400 mines have been opened in the basin (Lorenz, 1966) most of which have long been abandoned. Estimates by watershed as of 1962 indicate the opening of about 830 mines in the Moshannon Creek watershed, 1,150 in the Clearfield Creek watershed, 330 in the Bennett Branch Sinnemahoning Creek watershed and 180 in the Beech Creek watershed. The remaining mines were opened in the watersheds of minor tributaries to the West Branch upstream from the mouth of Loyalsock Creek.

Of the original bituminous coal reserves in the subbasin estimated to be 4,140 million tons in 1928 (Reese and Sisler, 1928) about 2,535 million tons still remained as recoverable reserves in 1963 (Central Pennsylvania Coal Producers Association). An estimated 1,334 million tons, more than half of the recoverable reserves, underlie Clearfield County. Coal production in the basin has been relatively stable, averaging about 9 million tons per year since 1945. Recently, Clearfield and Centre Counties have accounted for about 80 percent of the production in the basin (Wessel and others, 1964). Prior to 1945, deep mines accounted for most of the coal production in the basin; however, development of large earth-moving equipment during World War II greatly stimulated surface mining activity. Strip mining accounted for 45 percent of the Susquehanna River basin's production in 1945, 77 percent in 1955, and 84 percent in 1962. A gradual increase in production to 13.4 million tons in 2020 is projected (Wessel and others, 1964).

Mine Drainage Sources and Their Effect on Stream Quality

As shown in the table on the following page, there are presently about 967 major mine drainage sources in the West Branch basin. The drainage from these sources is causing continuous significant degradation of 540 miles of streams and intermittent significant pollution of 600 miles of streams.

For the years 1945-1953 and 1957-1958 the average sulfate loading was about 1,100 tons/day in the West Branch at Lewisburg. About 695 tons/day of this sulfate originated as mine drainage acidity. This estimate of the amount of acidity formed in the West Branch basin is substantiated by water quality data from Lock Haven (Figure 26) where sulfate loadings for the years 1946-1951, 1959, and 1962-1963 averaged 870 tons/day, with about 685 tons/day originating as mine drainage acidity. It is estimated that 250 tons/day of unneutralized acidity enters streams in the basin.

Mine Drainage Sources and Net
Acidity Contributions
West Branch Susquehanna River Basin

Area Sub-Area	Active Operations				Inactive Operations							
	Underground Mines		Surface Mines		Underground Mines		Surface Mines		Other Sources1/		Total Sources	
	No. of Sources	Net Acidity2/	No. of Sources	Net Acidity	No. of Sources	Net Acidity	No. of Sources	Net Acidity	No. of Sources	Net Acidity	No. of Sources	Net Acidity
West Branch Susquehanna River												
Headwaters Tributaries (Above Chest Creek)	5	5,000	2	100	97	22,500	31	1,900	7	24,000	142	53,500
Chest Creek	4	100	5	500	48	7,100	23	1,100	4	100	84	8,900
Anderson Creek			3	500	13	2,700	14	4,200			30	7,400
Clearfield Creek	1	100			50	19,200	20	15,000	22	2,400	95	36,900
Moshannon Creek			2	200	89	80,600	49	50,600	20	4,800	158	136,000
Sinnemahoning Creek	3	3,600			82	27,100	12	2,200	3	100	100	33,000
Beech Creek	1		5	1,200	35	8,000	51	12,000	21	800	113	22,000
Pine Creek					22	11,500	4	3,100			26	14,600
Minor Tributaries (Below Chest Creek)	5	4,000			124	87,900	63	14,500	27	80,300	219	186,700
(Sub-Total)	19	12,800	17	2,500	560	266,600	267	104,600	104	112,500	967	499,000

---

[1] Other inactive sources are abandoned refuse piles and seepages that can not be identified with specific sources.

[2] Net acidity in pounds per day.

A detailed discussion of the mine drainage sources in the West Branch Susquehanna River basin, and their effect on stream quality follows:

A. Headwaters to Chest Creek

A total of 142 major mine discharges have been located in this drainage area contributing approximately 27 tons/day net acidity. Most of the acid drainage in this reach originates in abandoned underground mines within the drainage of the upper nine miles of the West Branch. Numerous drainage sources exist in the remainder of the reach above Chest Creek, but they are alkaline.

The first major addition of mine drainage in this reach is the pumped discharge from an active deep mine. The discharge contributed a loading of 2 tons/day net acidity. This contribution was primarily responsible for the mean acidity concentration of 450 mg/l and an associated loading of 2.4 tons/day net acidity recorded on the West Branch about two miles downstream at mile 236 (see Figures 27 and 28).

Major mine drainage contributors within the next seven miles include three spoil piles and four abandoned deep mines. Their total contribution was 15 tons/day net acidity. The three spoil piles were responsible for about 30 percent of this total.

Between mile 229 and 220 the acidity concentration declined to 50 mg/l. The reduction is probably the result of the neutralizing action of naturally alkaline tributaries to the reach. Several of these tributaries have alkalinities in excess of 150 mg/l. From mile 220 to its confluence with Chest Creek, the West Branch does not exhibit a significant change in alkalinity, although a slight increase in other mine drainage indicators is evident.

In general, concentrations of mine drainage indicators declined throughout the length of the reach from the headwaters to Chest Creek. Mean iron and manganese concentrations, which were 120 and 3.6 mg/l, respectively, at the head of the reach, declined to 1.1 and 2.5 mg/l, respectively. Sulfates declined from 1,300 mg/l to 550 mg/l (see Figure 28).

1. Chest Creek

Chest Creek, during the survey period, contributed about 1 ton/day net alkalinity to the West Branch. Preliminary reconnaissance data indicate that, although Chest Creek was alkaline at its mouth during the survey period, a 3-mile reach is degraded by mine drainage that originates in the watershed of Brubaker Run (Figure 25). Mining activity has been very heavy in the Brubaker Run watershed. Sources of mine drainage include both underground and strip mines and refuse piles. Acid loads on the order of 2.0 tons/day from Brubaker Run degrade the quality of Chest Creek from its confluence with Brubaker Run to Westover. At Westover, a large alkaline discharge from a tannery neutralizes the acidity but significant levels of other mine drainage indicators remain.

A total of 84 drainage sources were located in the Chest Creek watershed contributing a total of 4.2 tons/day of acidity. Forty-two of these are in Brubaker Run, five of which discharge about 70 percent of the acidity that originates in the Chest Creek watershed. Inactive underground mines are the primary drainage source, but inactive surface mines are also significant contributors.

B. West Branch Susquehanna River-Chest Creek to Clearfield Creek

The West Branch Susquehanna River, from Chest Creek to Anderson Creek, varies between weakly acid and weakly alkaline, depending upon hydrologic conditions. The minor tributaries to this reach, although in general slightly influenced by mine drainage, contribute alkalinity. Acid contributions by Anderson Creek, Montgomery Creek, and Wolf Creek, totaling about 1.5 tons/day, were outweighed by alkaline contributions within the reach from Anderson Creek to Clearfield Creek.

The pH within the reach between Chest Creek and Clearfield Creek ranged from 3.1 to 7.6, the mean total iron concentration declined from 1.1 mg/l to 0.25 mg/l, and manganese and sulfate concentrations declined from 2.5 mg/l and 553 mg/l, respectively, to 0.05 mg/l and 270 mg/l, respectively. Fish and other aquatic life have been observed in this reach, although population is probably somewhat depressed by residual amounts of mine drainage.

1. Anderson Creek

Anderson Creek contributed an average of nearly 1 ton/day net acidity to the West Branch during the survey period. Most mining activity has been confined to the lower reaches of the watershed, and stream quality has not been seriously impaired by mine drainage upstream from the confluence with Little Anderson Creek (see Figure 25). Downstream from Little Anderson Creek, the stream is rendered acid by mine drainage from Little Anderson Creek. Minor tributaries downstream from Little Anderson Creek add to the acid loading of Anderson Creek. Mean total iron, manganese, and sulfate concentrations measured at the mouth were 3.9 mg/l, 3.4 mg/l, and 160 mg/l, respectively.

Most of the mine drainage in the watershed originates in abandoned mines. Although 30 discharges were observed, about 70 percent of the acid load measured originates in six discharges.

2. Clearfield Creek

Clearfield Creek is rendered acid by mine drainage from its source to its mouth. During an eight-week survey period in 1966, the stream contributed an average of 29 tons/day acidity to the West Branch. At the mouth, a mean net acidity concentration of 115 mg/l was measured. Total iron concentrations were relatively low (1.4 mg/l); however, other mine drainage indicators were present in high concentrations.

Although mining activity has been very extensive throughout most of the watershed, about 45 percent of the acid load in Clearfield Creek originates in 10 tributaries that have a combined drainage area of 95 square miles, or about 25 percent of the area of the Clearfield Creek watershed. The streams responsible for much of the acid load in Clearfield Creek are listed in Table 3 and their locations are indicated in Figure 29.

Table 3 - Principal Tributaries Contributing Mine Drainage to Clearfield Creek

Stream	Stream Mile (on Clearfield Creek)	Drainage Area (sq. mile)	Net Acid Loading (tons/day)
Roaring Run	1.3	12.2	1.0
Long Run	4.2	4.0	1.0
Potts Run	18.2	15.4	1.5
Upper Morgan Run	19.6	12.2	1.5
Lost Run	22.1	2.5	2.0
Japling Run	24.9	3.2	2.5
Muddy Run	25.5	30.6	13.5
Powell Run	45.7	11.2	1.3
Bluebaker Run	49.7	2.5	0.8
Trap Run	61.6	1.5	1.8

Ninety-five major mine drainage discharges were located in the Clearfield Creek basin. Field analysis of the discharges indicated that 16 of these major discharges, with a combined flow of 11 cfs, contributed abott 15 tons acidity per day, or about 60 percent of the acid load at the mouth.

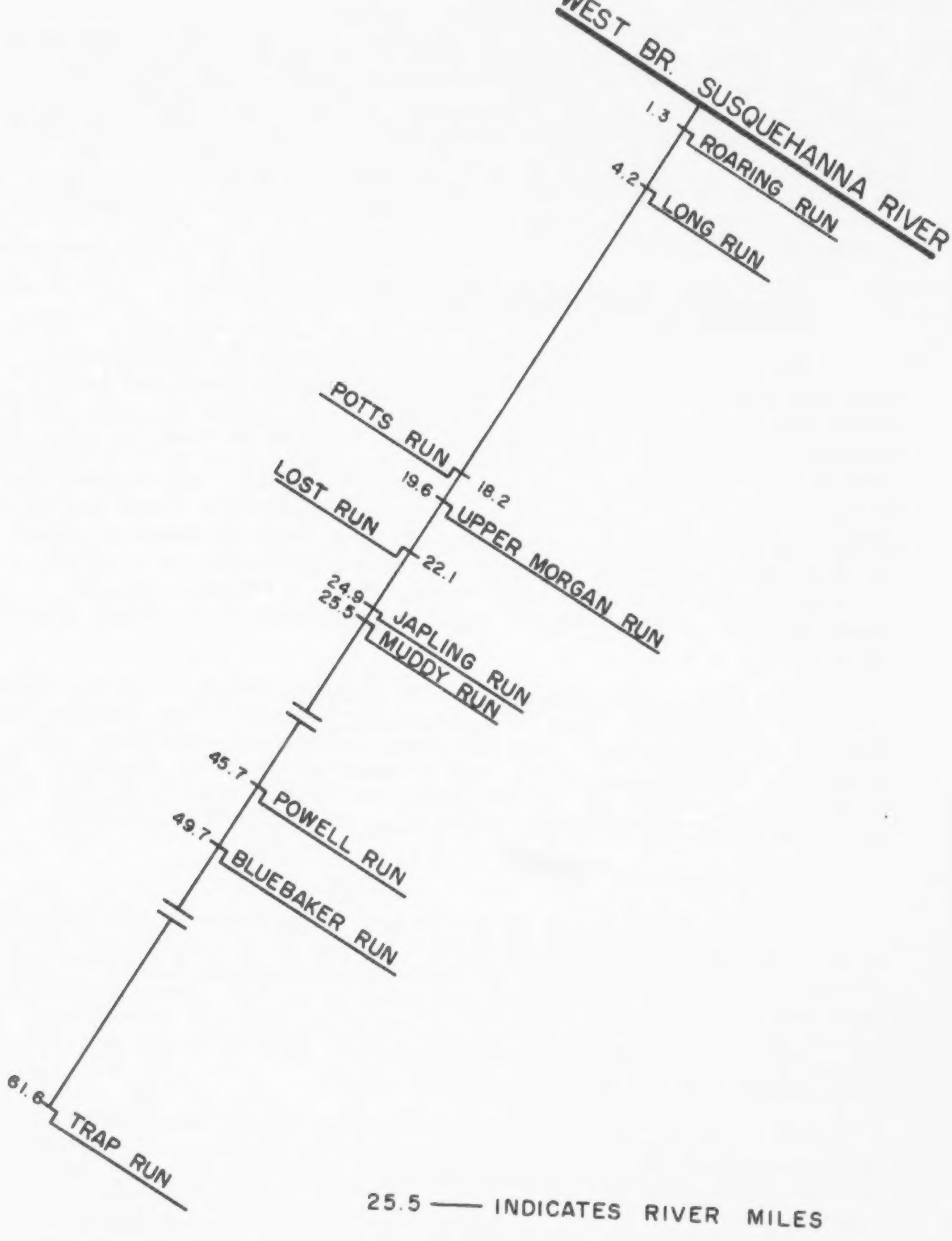

WEST BR. SUSQUEHANNA RIVER
1.3
ROARING RUN
4.2
LONG RUN
POTTS RUN
18.2
19.6
UPPER MORGAN RUN
LOST RUN
22.1
24.9
25.5
JAPLING RUN
MUDDY RUN
45.7
POWELL RUN
49.7
BLUEBAKER RUN
61.6
TRAP RUN
25.5 —— INDICATES RIVER MILES

Figure 29. Schematic diagram of streams affected by coal mine drainage pollution in the Clearfield Creek Watershed.

Most of the individual major discharges are discharges from strip mine areas; however, they are in many cases a combination of drainage from both deep and strip mines. Since in many cases strip mines have intercepted shallow underground mines or crossed underground mine portals, it is particularly difficult in the Clearfield Creek drainage basin to differentiate between underground and strip mine drainage. Essentially all the acid drainage located in the area is discharged from abandoned mines.

C. West Branch Susquehanna River-Clearfield Creek to Moshannon Creek

The quality of the West Branch in this reach is considerably affected by mine drainage contributed by Clearfield Creek and several minor tributaries within the reach. As shown in Figure 27, acid loadings increased from about 2 tons/day net alkalinity at the sampling point upstream from Clearfield Creek to 26 tons/day net acidity at the sampling point about 9 miles downstream from Clearfield Creek. The acidity concentration both upstream and downstream from Clearfield Creek was about 50 mg/l during the sampling period. The acid load increased to about 54 tons/day at mile 144, upstream from Moshannon Creek, as a result of acid contributions from minor tributaries. Iron and manganese concentrations of about 6 and 7 mg/l, respectively, were common (see Figure 28).

Tributaries that contribute mine drainage and that are not shown in Figure 25 include: Lick Run, Trout Run, Millstone Run, Surveyor Run, Murray Run, Congress Run, Deer Run, Sandy Creek, and Alder Run. The total acid contribution by the nine streams was about 20 tons/day. It is believed that most of the drainage originates in abandoned deep mines, with a somewhat lesser amount originating in abandoned strip mines.

1. Moshannon Creek

Moshannon Creek is the largest contributor of mine drainage to the West Branch Susquehanna River. During the survey period the stream contributed an average of about 65 tons/day net acidity to the West Branch. Stream quality at the mouth is fairly representative of stream quality throughout most of its length. Mean net acidity was 228 mg/l. Iron and manganese concentrations were 15.3 mg/l and 7.6 mg/l, respectively, during the survey period.

As in the Clearfield Creek basin, mining has been accomplished over most of the Moshannon Creek basin both by surface and subsurface methods. The quality of most of the streams in the watershed is influenced by mine drainage to some degree. A survey conducted in 1964 located 50 tributaries which were contributing acid to Moshannon Creek. The 10 streams listed in Table 4 are considered to be the most significant contributors of mine drainage. Figure 30 is a schematic representation of the principal mine drainage contributors to Moshannon Creek.

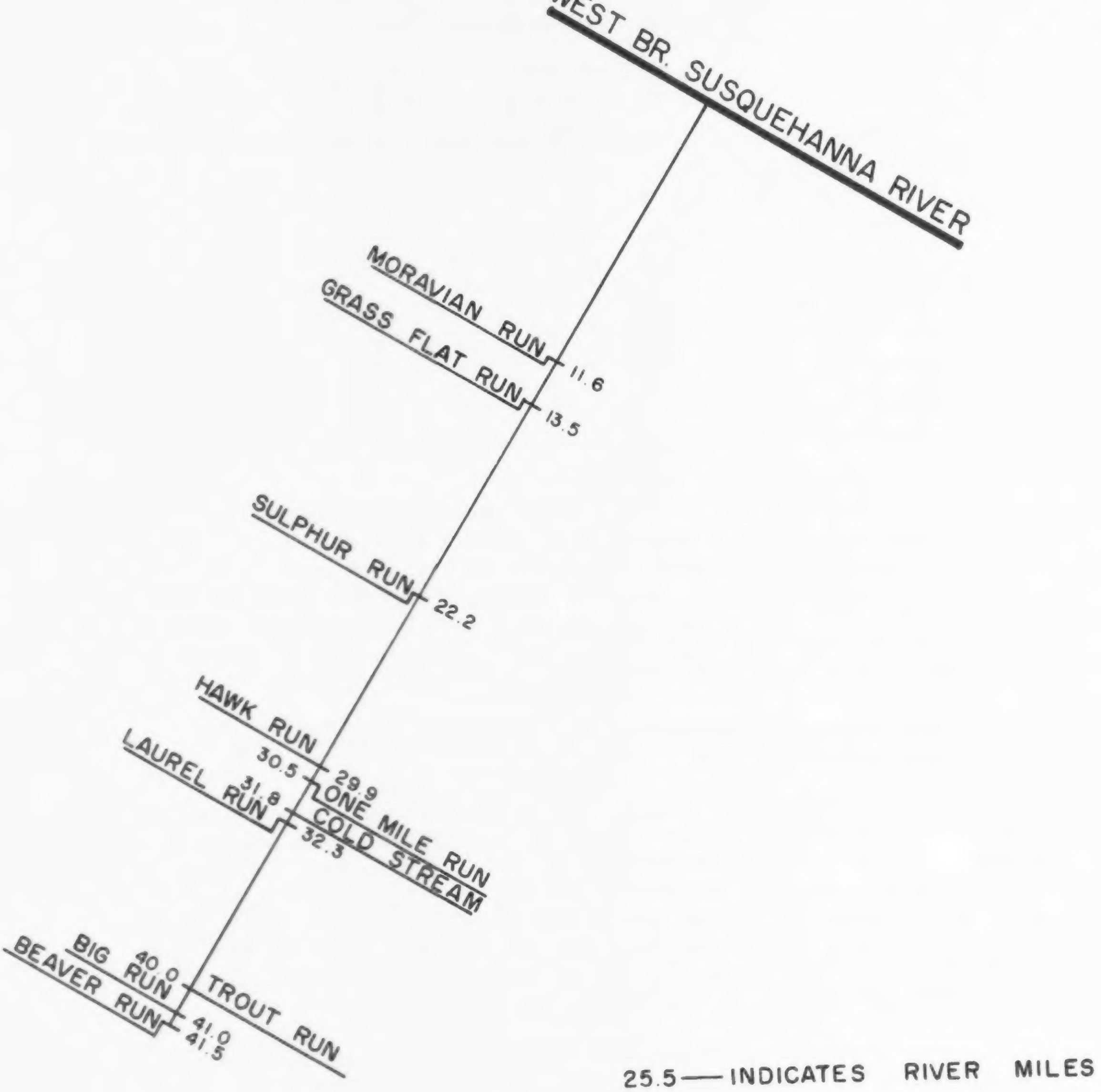

WEST BR. SUSQUEHANNA RIVER
MORAVIAN RUN
11.6
GRASS FLAT RUN
13.5
SULPHUR RUN
22.2
HAWK RUN
30.5
29.9
ONE MILE RUN
31.8
LAUREL RUN
COLD STREAM
32.3
40.0
BIG RUN
TROUT RUN
BEAVER RUN
41.0
41.5
25.5 — INDICATES RIVER MILES

Figure 30. Schematic diagram of streams affected by coal mine drainage pollution in the Moshannon Creek Watershed.

Table 4 - Principal Tributaries Contributing Mine Drainage to Moshannon Creek

Stream	Stream Mile (on Moshannon Creek)	Drainage Area (sq. mile)	Net Acid Loading (tons/day)
Moravian Run	11.6	1.8	11.5
Grass Flat Run	13.5	1.0	3.5
Sulphur Run	22.2	2.3	10
Hawk Run	29.9	2.4	8.2
One Mile Run	30.5	0.5	3
Cold Stream	31.8	23.6	6.2
Laurel Run	32.3	19.5	2.2
Trout Run	40.0	11.0	4.0
Big Run	41.0	2.5	1.6
Beaver Run	41.5	19.0	6.5

One hundred and fifty-eight discharges contributing about 68 tons/day acidity have been located in the Moshannon Creek basin. Of the 158 discharges, 26 contributed most of the acid load. Preliminary information indicates that one discharge contributes about 15 tons/day acidity, or about 20 percent of the acid load in Moshannon Creek at the mouth. As in the Clearfield Creek basin, essentially all of the mine drainage in this watershed originates in abandoned mines.

D. West Branch Susquehanna River-Moshannon Creek to Sinnemahoning Creek

In this reach the quality of the West Branch is severely degraded by mine drainage contributed in upstream reaches and by the Moshannon Creek. Acid concentrations and loadings vary slightly within the reach; however, the variations are not considered significant. Mean net acidity during the survey was about 130 mg/l. Sulfate concentrations were in the 800 to 1,000 mg/l range. Most of the minor tributaries to this reach are mildly acid or mildly alkaline and have no significant effect on the quality of the West Branch.

Mine drainage location and characterization work has not been completed in this watershed; however, it is known that only a limited amount of mining has been accomplished and that acid drainage originates in abandoned underground mines.

1. Sinnemahoning Creek

During the study period Sinnemahoning Creek contributed about 18 tons/day net acidity to the West Branch. The creek, with its drainage area of 1,032 square miles, has the largest watershed area tributary to the West Branch. It encompasses approximately 40 percent of the area of the West Branch basin at their confluence. Major tributaries include the First Fork, Bennett Branch, and Driftwood Branch. Although the stream has a large watershed area, topographic and geologic conditions combine to produce "flashy" flow characteristics with low drought flows and low natural alkalinity reserves in the stream. These characteristics combine to give it a very poor capacity to assimilate mine drainage discharges.

Although most of the watershed lies within the bituminous coal fields, mining activity has been restricted almost exclusively to the watersheds of the Bennett Branch Sinnemahoning and Sterling Run, a minor tributary to the Driftwood Branch Sinnemahoning. The Bennett Branch is essentially acid from its source to its mouth. It, in turn, renders Sinnemahoning Creek acid from their confluence to its mouth. Sterling Run, while not overcoming the alkalinity reserve in the Driftwood Branch, does add mine drainage indicators.

Although quite acid (136 mg/l net acidity), the Bennett Branch was found to contain relatively lower concentrations of other mine drainage indicators. The mean total iron and manganese concentrations were, for example, 1 mg/l, and 4.1 mg/l, respectively, during the survey period. Concentrations of most mine drainage indicators at the mouth of Sinnemahoning Creek are about half of Bennett Branch concentrations, reflecting the diluting effect of other tributaries of Sinnemahoning Creek.

A total of 100 discharges have been located in the Bennett Branch watershed, most of which originate in abandoned underground mines. Nine underground mine discharges contribute 12 tons/day of acidity, more than 65 percent of the total contributed by the 100 discharges.

E. West Branch Susquehanna River-Sinnemahoning Creek to Mouth

As shown in Figure 27, the quality of the West Branch in this reach changes significantly in response to several major influences, but particularly in response to the influence of Bald Eagle Creek.

Acid contributed by Sinnemahoning Creek was responsible for a 7.5 tons/day net acidity increase in the acid load in the West Branch below the creek mouth during the survey period. The contribution of an additional 7.5 tons/day acidity by Kettle Creek further increased the acid loading in the West Branch below that tributary. Although acid concentrations do not vary appreciably between Kettle Creek and North

Bald Eagle Creek, net acidity loadings increase with increases in flow at successive sampling stations. The apparent increase in loading is believed to be primarily the result of limitations in the precision of analysis and flow measurement procedures, and not to mine drainage discharges in the reach.

At Lock Haven (mile 68), North Bald Eagle Creek, with its contribution of 66 tons/day net alkalinity during the survey period enters the West Branch and contributes most of the alkalinity required to neutralize the acid load in the West Branch. Other major alkaline tributaries in the reach between Lock Haven and Williamsport (mile 040) that contribute to the neutralization of the West Branch include Pine Creek, Larry's Creek, Lycoming Creek, and Antes Creek.

Downstream from Williamsport, the West Branch is normally weakly alkaline (10 mg/l net alkalinity) and receives no direct mine drainage discharges. During unusual flow conditions, when the ratio of the flow in the West Branch to the flow in North Bald Eagle Creek is considerably higher than normal, the acid load carried by the West Branch is not neutralized, and acid conditions prevail downstream from Williamsport, sometimes to the mouth of the West Branch. This condition frequently occurs in late summer in conjunction with heavy rains in the Clearfield and Moshannon Creek watersheds with no corresponding rainfall in the North Bald Eagle Creek watershed. The condition, normally a once-yearly occurrence, causes extensive fish kills downstream from Williamsport.

1. Kettle Creek

Kettle Creek, with its contribution of 7.5 tons/day acidity during the survey period, is the most downstream direct source of mine drainage to the West Branch. Throughout most of its length, Kettle Creek flows through heavily forested land and is considered an excellent trout stream. In its lower 2 miles, its naturally low alkalinity is overcome by mine drainage contributed by Two Mile Run and discharges that enter directly.

2. North Bald Eagle Creek

North Bald Eagle Creek is responsible for neutralizing most of the acid load in the West Branch. Its contribution of 66 tons/day alkalinity during the survey period was the largest single source of alkalinity to the West Branch.

Considerable mining has taken place in the North Bald Eagle Creek drainage basin, however, and the quality of the lower reaches of the stream is influenced by mine drainage. Essentially all the mining in the basin has been accomplished in the watershed of Beech Creek, a major tributary. Beech Creek is acid from its source to its mouth and contributed about 5 tons/day net acidity to North Bald Eagle Creek during the survey period. Under most natural flow conditions, the alkalinity in North Bald Eagle Creek is adquate to neutralize the acid contributed by Beech Creek. During periods of unbalanced rainfall and runoff in the basin, high flows from Beech Creek have significantly reduced the alkalinity in North Bald Eagle Creek. Flow regulation by Blanchard Dam, a multi-purpose structure now under construction immediately upstream from Beech Creek, may tend to accentuate this condition.

Mining conditions in the Beech Creek watershed are very similar to those in the nearby Clearfield and Moshannon Creek watersheds. Much of the watershed has been mined, both by surface and underground methods. Although more than a hundred mine drainage discharges have been located in the watershed, preliminary evaluation of the data indicates that most of the acid originates in six major discharges.

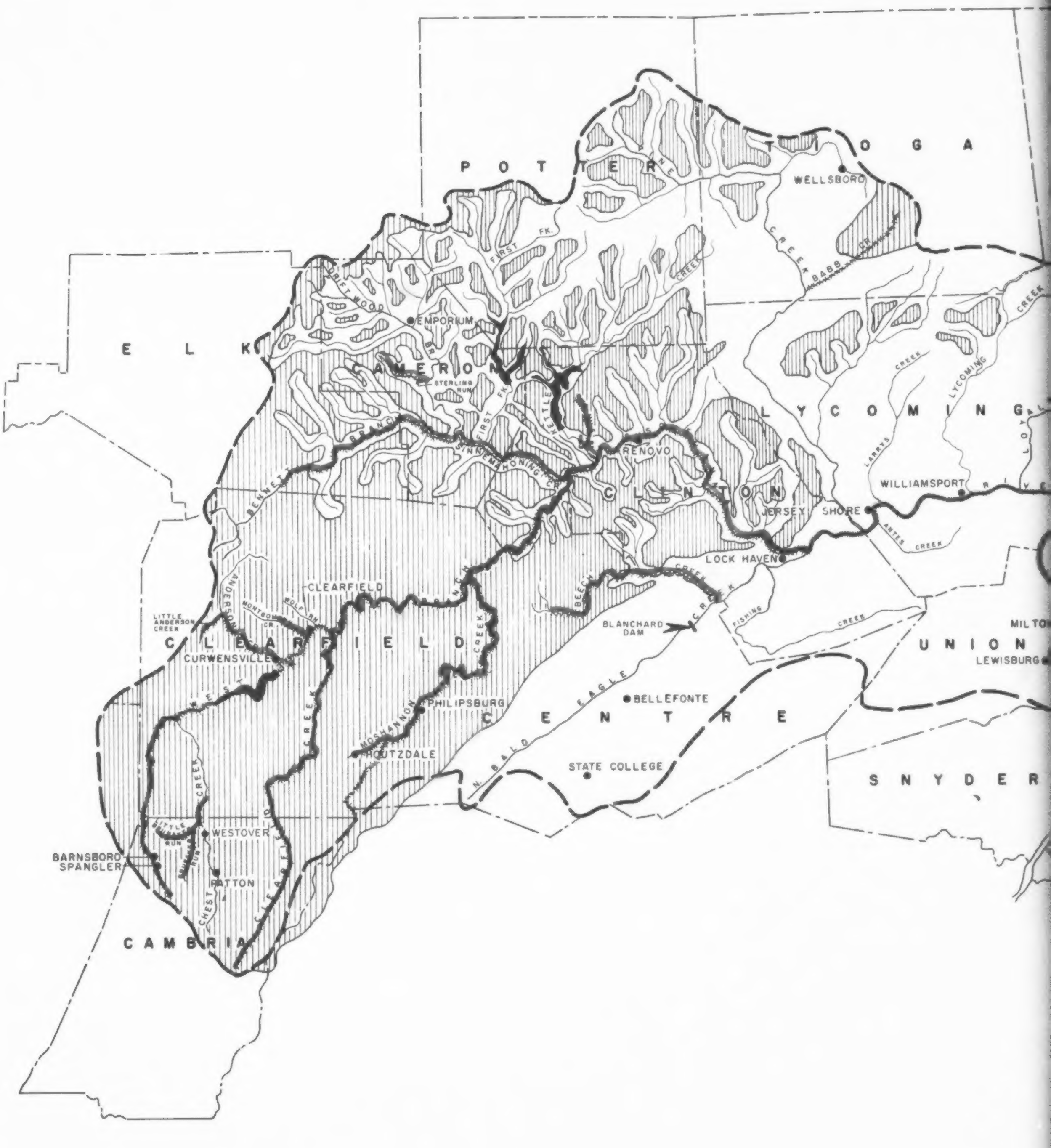
3. Pine Creek

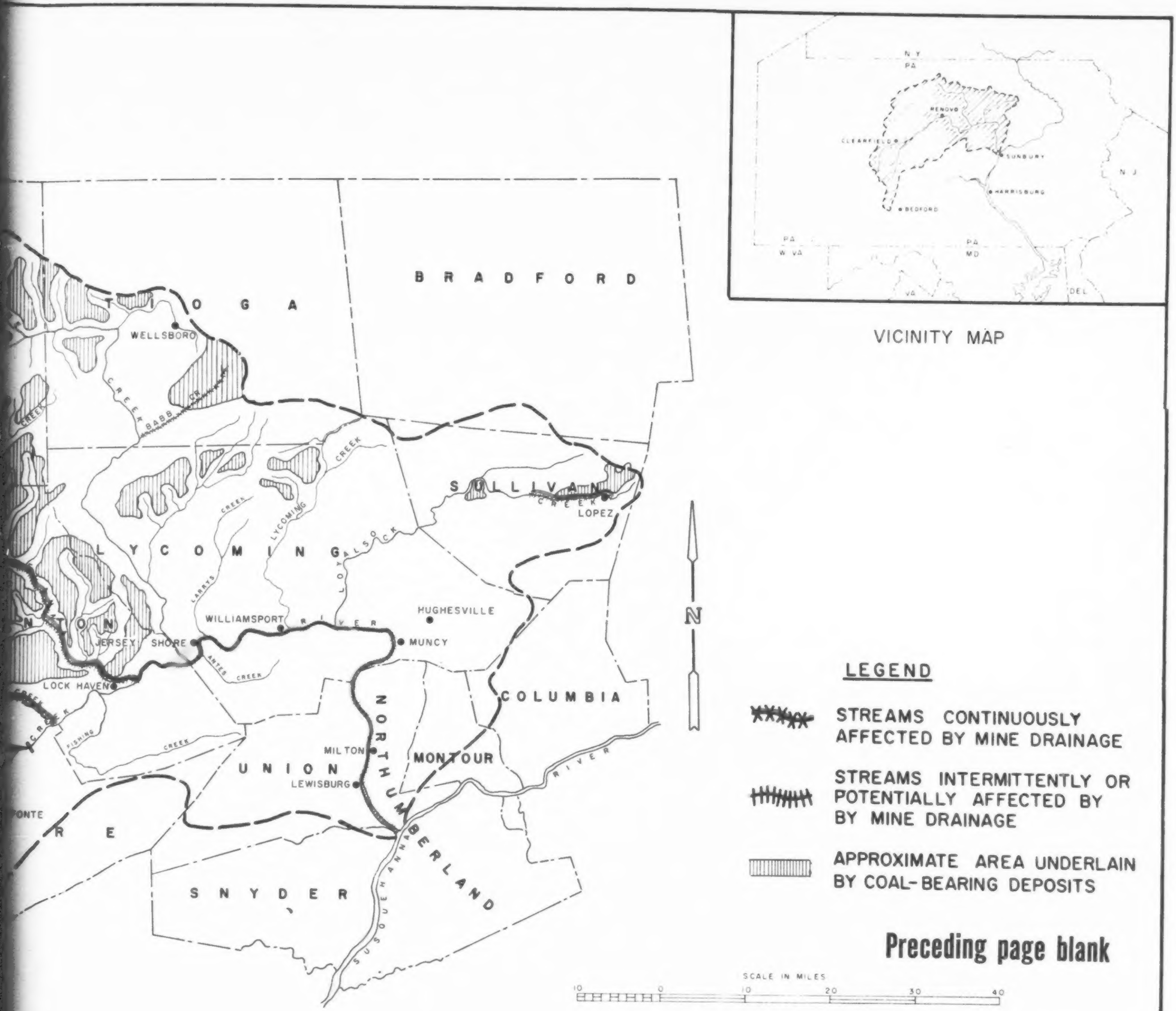
In the Pine Creek watershed, intense mining activity in the headwaters of Babb Creek (Fig. 25) has produced drainage which degrades the quality of Babb Creek throughout its length. Twenty-eight discharges have been located in the watershed, but six discharges are responsible for three-quarters of the total net acidity contribution of 7.5 tons/day. Babb Creek is slightly acid at its mouth, but it has no significant effect on Pine Creek which contributes an alkaline load to the West Branch Susquehanna River.

4. Loyalsock Creek

Although Loyalsock Creek is an alkaline stream at its mouth and bears no significant evidence of mine drainage indicators throughout most of its length, it does receive mine drainage from abandoned mines in an isolated semianthracite deposit in the headwaters.

Two drainage tunnels near the Village of Lopez (see Figure 25) discharge mine drainage with a net acidity concentration of approximately 60 mg/l. The addition of this slightly acid discharge to the stream, which has a naturally low residual alkalinity, causes degradation for approximately eight miles downstream.


POTTER
TIOGA
WELLSBORO
PINE
FIRST FK.
CREEK
BABB CR.
CREEK
ELK
DRIFTWOOD
EMPORIUM
BR.
CAMERON
STERLING RUN
FIRST FK.
KETTLE
BRANCH
SINNEMAHONING CR.
RENOVO
CLINTON
LYCOMING
CREEK
LYCOMING
CREEK
LARRYS
LOYAL
WILLIAMSPORT
RIVER
JERSEY SHORE
ANTES CREEK
LOCK HAVEN
BENNETT
ANDERSON
CLEARFIELD
MONTGOMERY CR.
WOLF RN.
BRANCH
LITTLE ANDERSON CREEK
CLEARFIELD
CURWENSVILLE
CREEK
WEST
BEECH
CREEK
BLANCHARD DAM
FISHING
CREEK
MILTON
UNION
LEWISBURG
PHILIPSBURG
MOSHANNON
HOUTZDALE
CENTRE
BELLEFONTE
N. BALD EAGLE
STATE COLLEGE
SNYDER
CREEK
LITTLE
RUN
RUN
WESTOVER
BARNSBORO
SPANGLER
PATTON
CHEST
CLEARFIELD
CAMBRIA


N.Y.
PA
RENOVO
CLEARFIELD
SUNBURY
HARRISBURG
BEDFORD
N.J.
PA
W.VA.
PA
MD
VA
DEL
VICINITY MAP
BRADFORD
TIOGA
WELLSBORO
BABB CR
CREEK
SULLIVAN
CREEK
LOPEZ
LYCOMING
LYCOMING
LARRYS
LOYALSOCK
HUGHESVILLE
WILLIAMSPORT
RIVER
MUNCY
JERSEY SHORE
ANTES CREEK
LOCK HAVEN
FISHING CREEK
COLUMBIA
NORTHUMBERLAND
MILTON
MONTOUR
UNION
LEWISBURG
RIVER
SNYDER
SUSQUEHANNA
N
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
SCALE IN MILES
10
0
10
20
30
40

Preceding page blank

APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 25

WEST BRANCH
SUSQUEHANNA RIVER BASIN

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

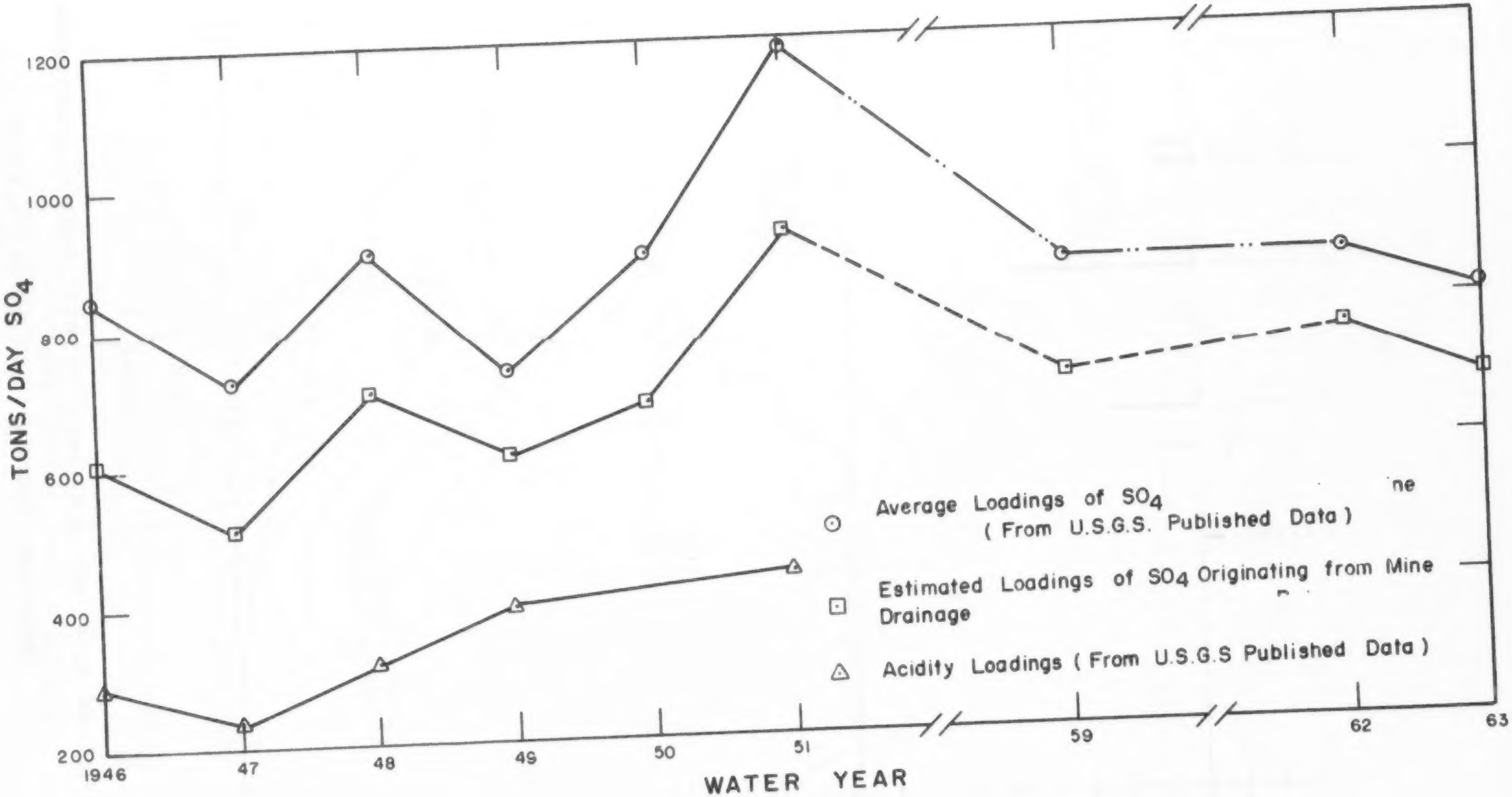


Figure 26. Average loads of acidity, total sulfate and sulfate considered to originate from coal mine drainage carried by the West Branch Susquehanna River at Lock Haven, Pennsylvania.

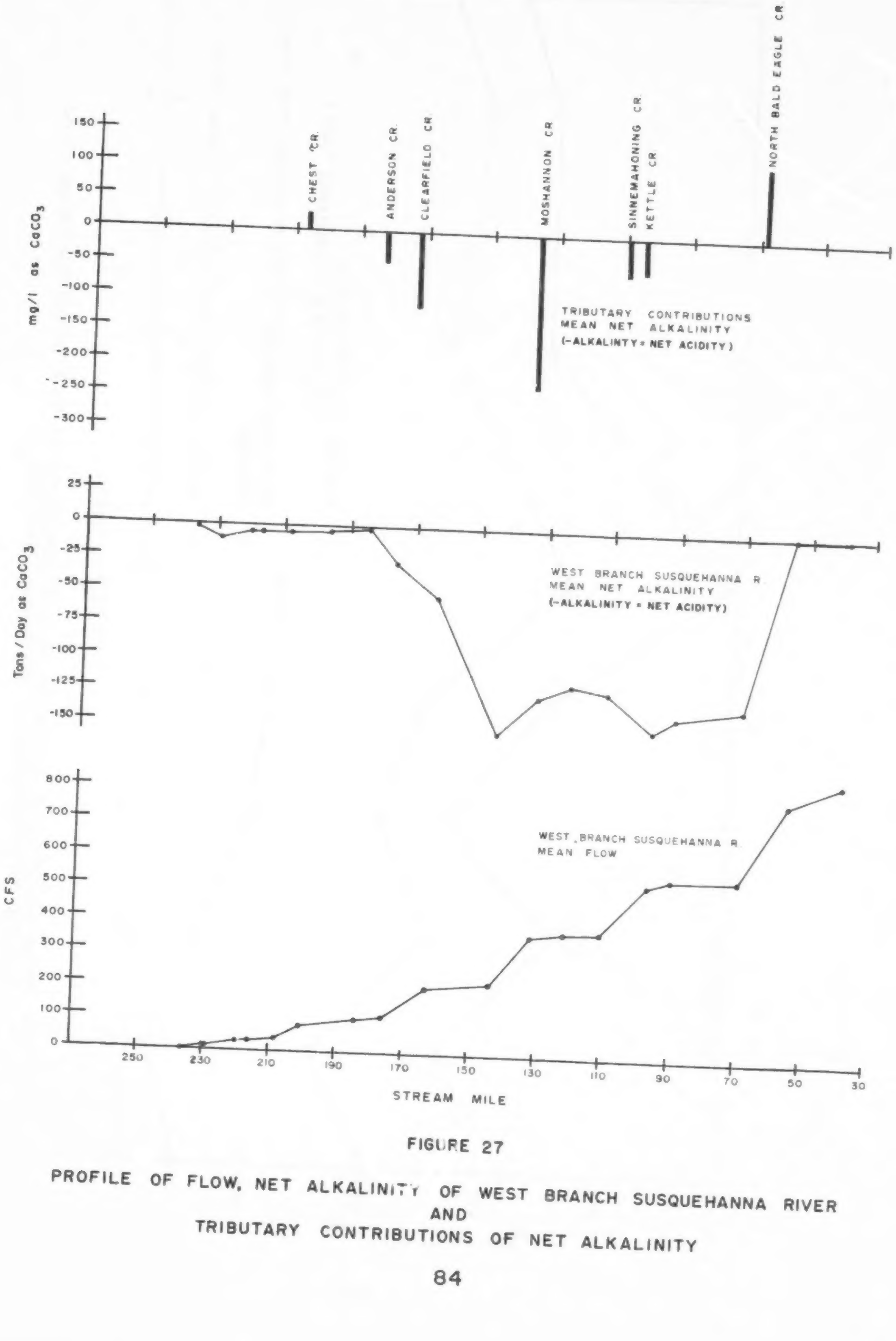


FIGURE 27

PROFILE OF FLOW, NET ALKALINITY OF WEST BRANCH SUSQUEHANNA RIVER
AND
TRIBUTARY CONTRIBUTIONS OF NET ALKALINITY

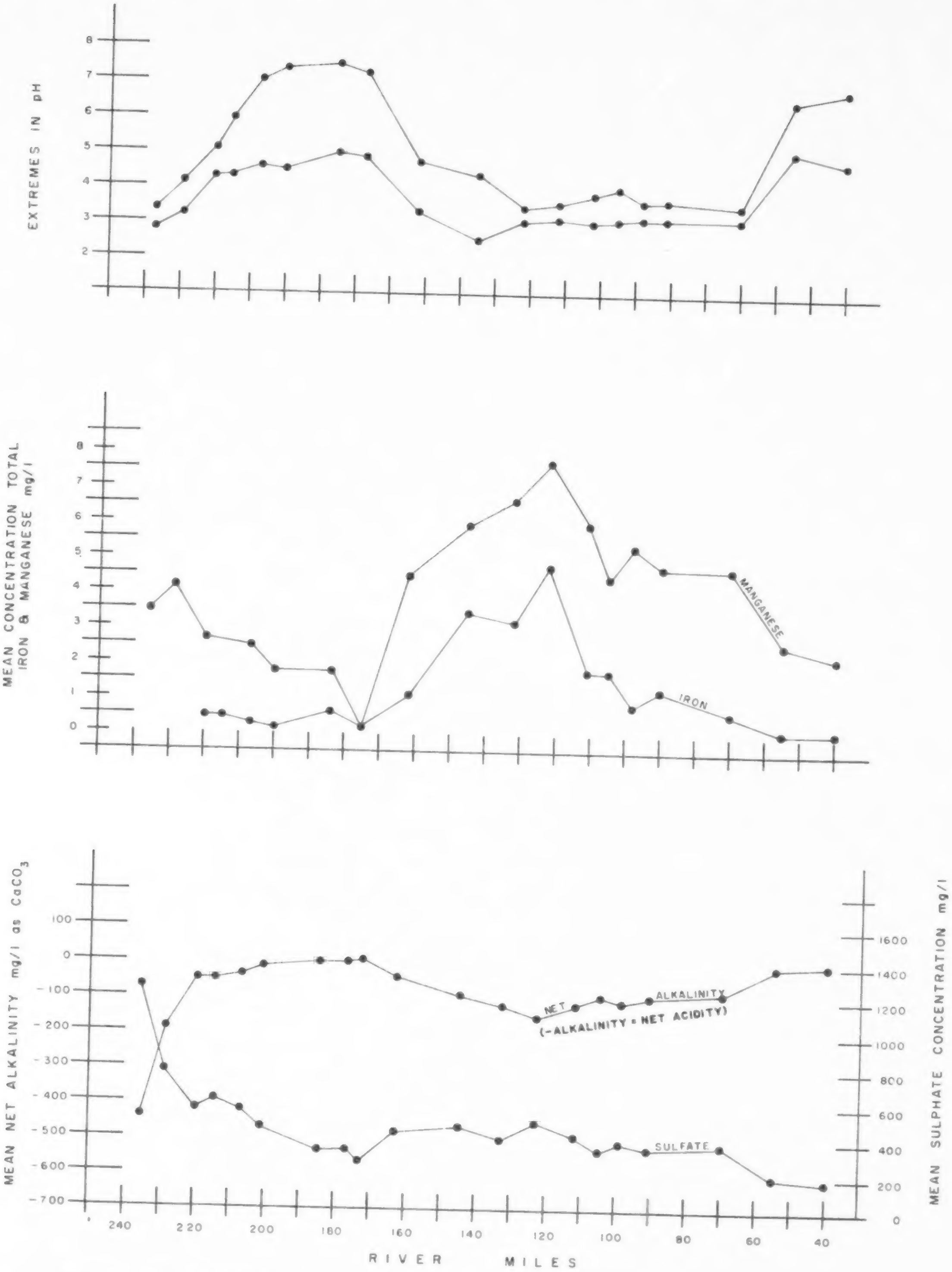


FIGURE 28 PROFILE OF pH, MANGANESE, IRON & SULFATE CONCENTRATION AND NET ALKALINITY

WEST BRANCH, SUSQUEHANNA RIVER

Juniata River Basin

Description

The Juniata River, 86 miles long with a drainage area of 3,406 square miles, is formed by the junction of the Little Juniata River and Frankstown Branch Juniata River at Huntingdon, Pennsylvania. The stream flows easterly by a circuitous route to its confluence with the Susquehanna River (see Figure 31).

Virtually the entire Juniata River basin lies within the Valley and Ridge Province. This area is characterized by an alternate succession of long ridges and valleys, that trend generally southwest-northeast. The ridges in the western part of the basin are steep and rugged, whereas, the eastern part is considerably more rolling in nature. A small area on the western edge of the basin drains a part of the Appalachian Plateau Province. Elevations range from 340 to 2,900 feet above sea level.

The coal fields influencing stream quality are located in the southwestern portion of the watershed. The largest coal deposit in the watershed is the Broad Top coal field, located in Bedford, Huntingdon, and Fulton Counties. The field, approximately 81 square miles in area, lies in a highly dissected plateau known as Broad Top Mountain and is east of the Allegheny Mountains, totally isolated from the main bituminous coal fields.

A small portion of the main bituminous coal field lies within the watershed on the western edge of Blair County along the eastern slope of Allegheny Mountains.

The first authenticated record of coal mining in the area occurred during the Revolutionary War. The first commercial shipments were made in 1853, reaching a peak production of approximately 2.7 million tons in 1918. By 1964 coal production had diminished to about 0.4 million tons.

Projections of production in the Juniata basin are as follows (Wessel and others, 1964):

Projected Bituminous Production (Thousand Tons)

1970	1985	2020
490	780	1,520

Reserves of coal have been estimated to total 215 million tons of which approximately 129 million tons are recoverable (Wessel, 1966).

Preceding page blank

Mine Drainage Sources and Their Effect on Stream Quality

About 44 significant mine drainage sources that contribute about 19 tons/day of acidity exist in the Juniata River basin, all of which originate in abandoned underground mines. The drainage from these sources is causing continuous significant degradation of 60 miles of streams and intermittent significant degradation of 20 miles of streams.

The average loadings of sulfate in the Frankstown and Raystown Branches of the Juniata River in the years for which data are available were 87 tons/day and 70 tons/day, respectively. Of these sulfate loads 32 tons/day in the Frankstown Branch and 28 tons/day in the Raystown Branch are considered to have resulted from mine drainage acidity, indicating a total of about 60 tons/day of acidity formed in the Juniata basin. It is estimated that 19 tons/day of unneutralized acidity enters streams in the basin.

A. Little Juniata River

Mining activity in this basin has been limited almost exclusively to the Bells Gap Run watershed which has been extensively deep and strip mined.

Sampling of the Little Juniata River upstream from the confluence with Bells Gap Run (Figure 31) indicated an initial net alkalinity of 100 mg/l accompanied by low level concentrations of other mine drainage indicators. Bells Gap Run, despite mine drainage contributions, exhibits very little evidence of mine drainage indicators at its mouth and contributes an alkaline loading of approximately 170 lbs/day to the Little Juniata River.

B. Frankstown Branch Juniata River

The Frankstown Branch exhibited an alkaline reserve of 110 mg/l net alkalinity at its confluence with the Little Juniata during the sampling period. The stream, while alkaline, contains significant levels of iron and hardness, mine drainage indicators.

The major contributor of mine drainage during the sampling period was the Beaver Dam Branch, which contributed approximately 1.5 tons/day net acidity. The major sources of mine drainage to the Beaver Dam Branch were Burgoon Run and Sugar Run.

Burgoon Run receives mine drainage from Kittanning Run and Glenwhite Run, small streams whose watersheds have been almost completely disturbed by surface mining. Kittanning Run is diverted around a public water supply reservoir serving the city of Altoona and enters Burgoon Run downstream from the reservoir. The flow of the upper reaches of Burgoon Run and the normal flow of Glenwhite Run form the reservoir supply. During periods of high runoff, however, the flow of Glenwhite Run is also diverted to the by-pass.

Sugar Run had an acid loading at its mouth of 0.5 tons/day net acidity. Most of the acid originates in the discharge from one abandoned deep mine.

C. Raystown Branch Juniata River

Mine drainage in this drainage basin originates in the Broad Top Coal Field and is conveyed to the Raystown Branch by Longs Run, Six Mile Run, Shoups Run, and Great Trough Creek. Each of the first three streams is acid from its source to its mouth. Great Trough Creek is acid through its length in the coal fields, approximately five miles. Alkaline tributaries neutralize the acid load and provide an alkaline reserve at its mouth.

The three acid streams contributed the following acid loading to the Raystown Branch during the survey period:

Longs Run, 2.5 tons/day net acidity
Six Mile Run, 1.4 tons/day net acidity
Shoups Run, 1.6 tons/day net acidity

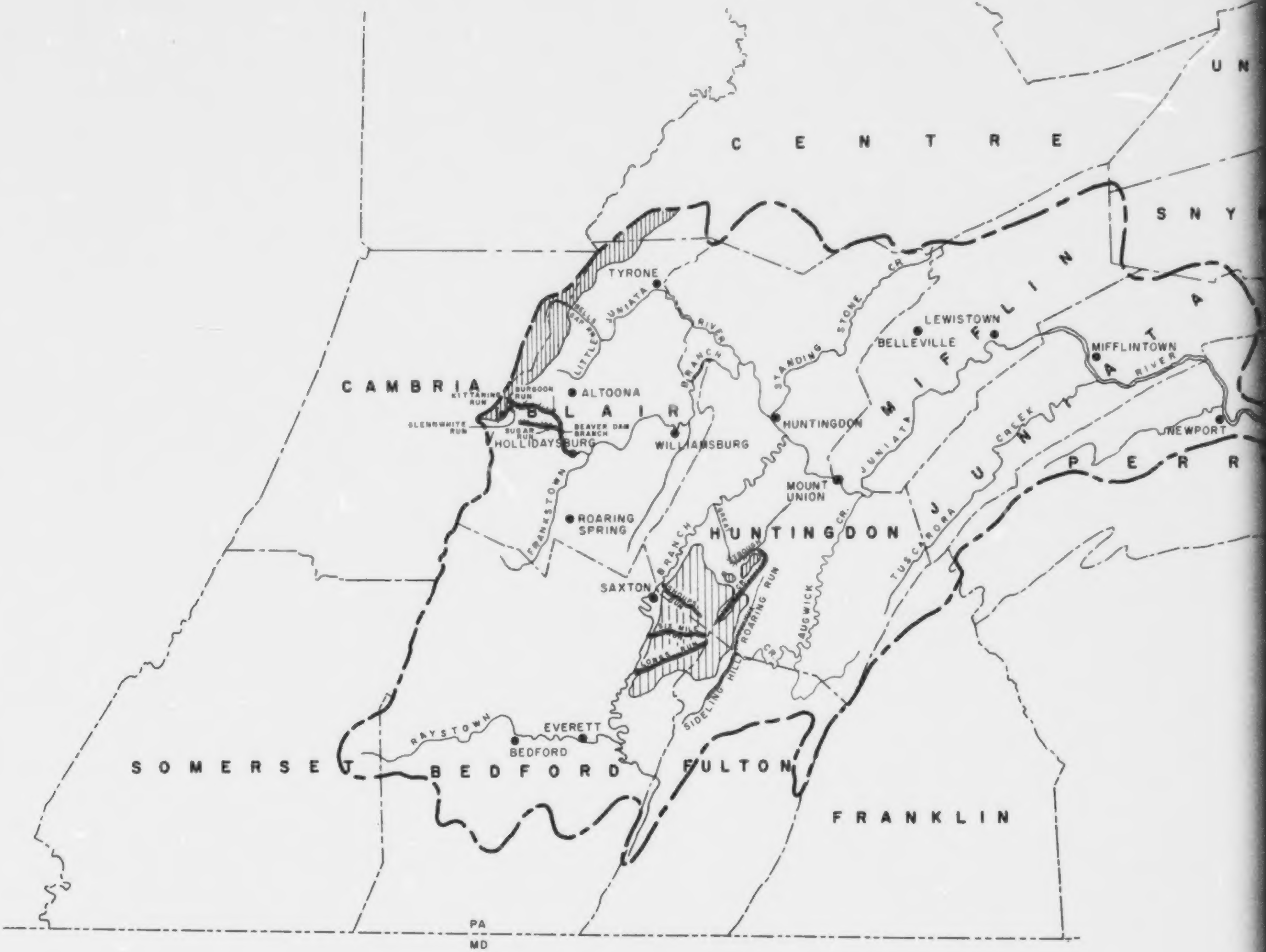
In spite of the sizable acid contributions, as shown in Figure 32, the alkaline reserve of Raystown Branch upstream (21 tons/day during the sampling period) was more than ample to assimilate the acid contributed. The Raystown Branch downstream from the coal field exhibited essentially no evidence of the mine drainage loading.

Water quality in the three acid streams was generally comparable. They had pH values of less than 4.5, and elevated concentrations of manganese, sulfate, hardness, and other mine drainage indicators. Inexplicable, the iron concentration in Shoups Run was normally less than 1 mg/l; while in Longs Run and Six Mile Run, mean concentrations exceeded 10 mg/l.

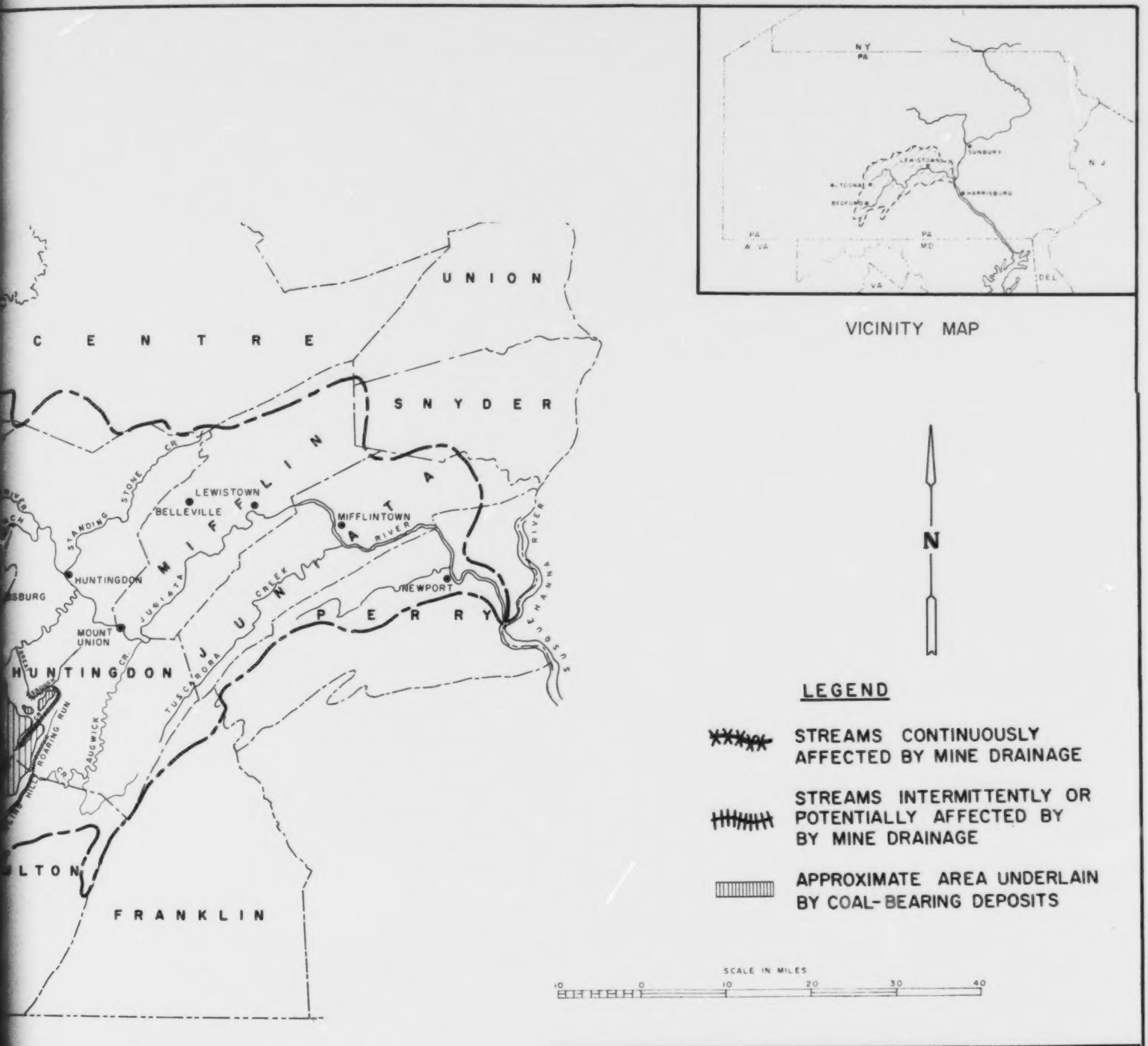
Almost all of the mine drainage discharges located in the watersheds tributary to the Raystown Branch originated in deep mines. A limited amount of surface mining has taken place in the basin and may be influencing deep mine discharges; however, no surface discharges were observed.

D. Aughwick Creek

A small percentage of the Broad Top coal fields lies in the Aughwick Creek basin. Roaring Run, a tributary of Sidling Hill Creek, which in turn is tributary to Aughwick Creek, is the only known contributor of mine drainage in the basin. Roaring Run with its acid loading of 750 lbs/day during the sampling period degraded the quality of Sidling Hill Creek at their confluence. Alkalinity contributed by other tributaries enabled Sidling Hill Creek to recover from the acid loading and have an alkaline reserve at its mouth.


CENTRE
UN
SNY
CAMBRIA
BLAIR
TYRONE
ALTOONA
HOLLIDAYSBURG
WILLIAMSBURG
ROARING SPRING
KITTANING RUN
BURGOON RUN
GLENWHITE RUN
SUGAR RUN
BEAVER DAM BRANCH
BELLS GAP RN
LITTLE
JUNIATA
RIVER
BRANCH
FRANKSTOWN
STANDING STONE CR
HUNTINGDON
MOUNT UNION
HUNTINGDON
LEWISTOWN
BELLEVILLE
MIFFLIN
JUNIATA
MIFFLINTOWN
RIVER
NEWPORT
JUNIATA
CREEK
TUSCARORA
PERR
SAXTON
BRANCH
GREAT
TROUGH
CR
SHOUPS RUN
SIX MILE RUN
LONGS RUN
ROARING RUN
SIDELING HILL
AUGWICK
CR
JUNIATA
RAYSTOWN
EVERETT
BEDFORD
SOMERSET
BEDFORD
FULTON
FRANKLIN
PA
MD

A


VICINITY MAP
NY
PA
SUNBURY
LEWISTOWN
ALTOONA
BEDFORD
HARRISBURG
N J
PA
W VA
PA
MD
VA
DEL
UNION
CENTRE
SNYDER
MIFFLIN
JUNIATA
PERRY
HUNTINGDON
ULTON
FRANKLIN
LEWISTOWN
BELLEVILLE
MIFFLINTOWN
NEWPORT
HUNTINGDON
MOUNT UNION
SBURG
STANDING STONE CR
JUNIATA RIVER
TUSCARORA CREEK
AUGWICK CR
ROARING RUN
SUSQUEHANNA RIVER
N
LEGEND
✕✕✕✕ STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
‡‡‡‡ STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
▥ APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
SCALE IN MILES
10
0
10
20
30
40

APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 31

JUNIATA RIVER BASIN

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

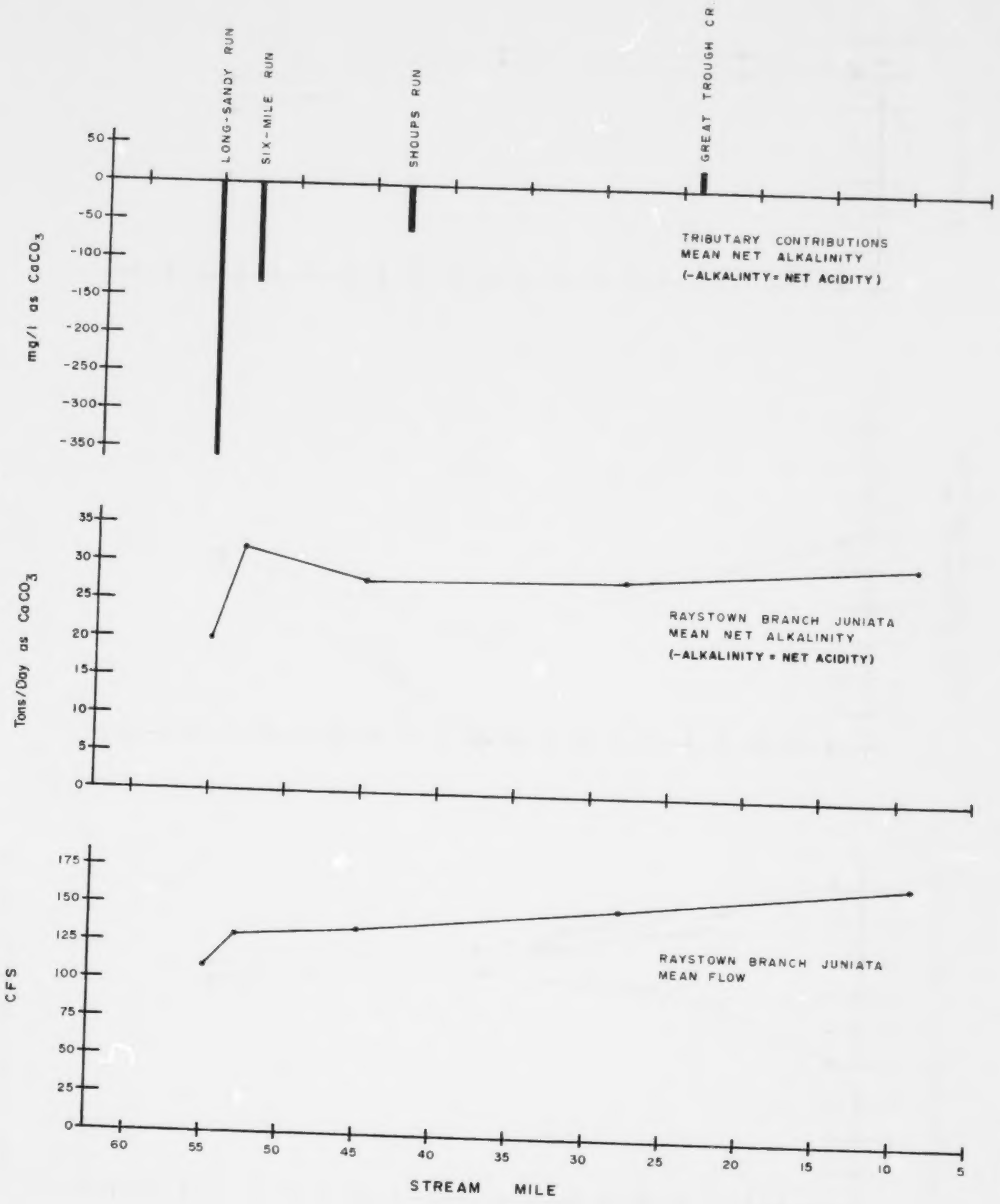


FIGURE 32

PROFILE OF FLOW, NET ALKALINITY OF RAYSTOWN BRANCH JUNIATA RIVER AND TRIBUTARY CONTRIBUTIONS OF NET ALKALINITY

Preceding page blank

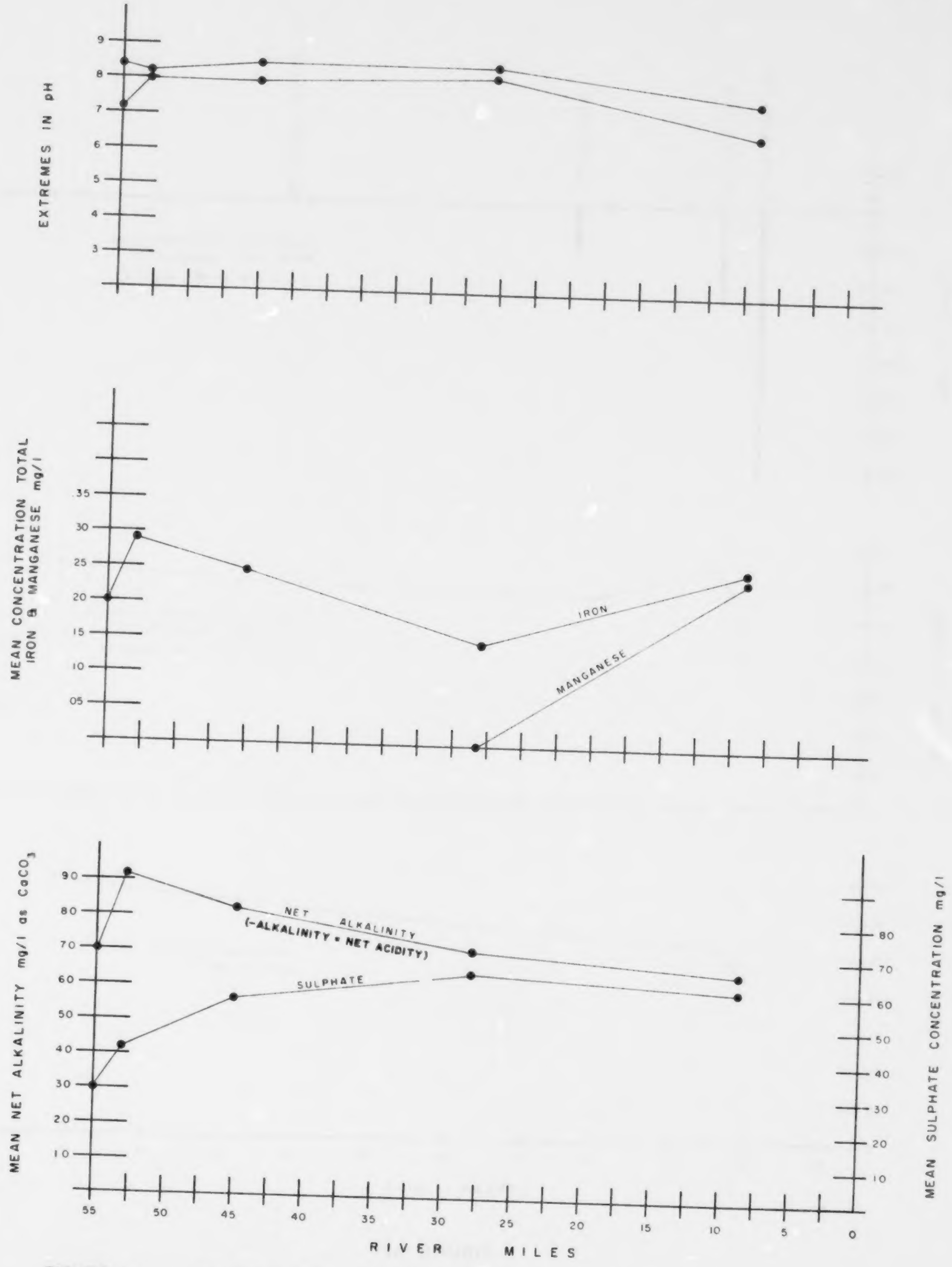


FIGURE 33 PROFILE OF pH, MANGANESE, IRON & SULFATE CONCENTRATION AND NET ALKALINITY
RAYSTOWN BRANCH, JUNIATA RIVER

North Branch Potomac River

Description

The North Branch of the Potomac River rises in Tucker County, West Virginia, and flows alternately northeast and southeast in a zigzag pattern for about 98 miles until it meets the South Branch to form the Potomac River (Figure 34).

The North Branch forms the boundary between Maryland and West Virginia downstream from Kempton, Maryland. The North Branch is bounded on the Maryland side by Garrett and Allegheny Counties and on the West Virginia side by Grant, Mineral, and Hampshire Counties.

The coal-bearing area of the North Branch basin lies in a continuous trough-shaped valley about 80 miles long, oriented in a northeast-southwest direction. The North Branch flows northeast through the center of the basin for almost two-thirds of its length. The northeast part of the valley is drained by Georges Creek, which flows southwest through the center of the valley to join the North Branch at Westernport. The coal-bearing region southwest of Westernport is known as the Upper Potomac coal fields. The coal region drained by Georges Creek, Savage River, and two small tributaries of Wills Creek is known as the Georges Creek coal field. Coal is mined from the Pittsburgh, Tyson, Bakerstown, Waynesburg, Freeport, and Kittanning coal seams.

Coal has been mined in the North Branch basin for about 150 years. Maryland's peak production of coal occurred in 1907, earlier than any other major coal-producing state. Coal production in the North Branch basin for the 1961-1965 period was:

1961 - 1.0 million tons
1962 - 1.0 million tons
1963 - 1.3 million tons
1964 - 2.2 million tons
1965 - 3.3 million tons

About 2.2 million tons were mined in West Virginia (Upper Potomac Field) and 1.1 million tons in Maryland in 1965. The Upper Potomac field accounted for 85 percent of the 1965 North Branch basin coal production. In 1961 and 1962, Maryland accounted for about 75 percent of the coal produced in the North Branch basin; in 1965 Maryland accounted for only 33 percent.

Mine Drainage Sources and Their Effect on Stream Quality

During the sampling program conducted by the Chesapeake Bay-Susquehanna River Basins Project of the FWPCA in August and October 1966 and April 1967, the North Branch of the Potomac River was found to be acid as a result of coal mine drainage from its source to Luke, Maryland. Until recently, spent process lime discharged by the West Virginia Pulp and Paper Company's Luke Mill neutralized the acid contributed upstream; but the lime is no longer discharged and acid conditions will extend further downstream in the future. Sampling by the Maryland Department of Water Resources (MDWR) in April, July, and November 1966 and a period of continuous monitoring by MDWR in April 1967 revealed similar conditions. This report is based partly on the MDWR data. The data are the result of year-round sampling programs rather than low flow surveys. They do, however, represent water quality at below average and relatively uniform conditions.

From its source to the area of Westernport, Maryland, where it leaves the coal region, the North Branch receives acid mine drainage from at least eleven tributaries (see Figure 34). Of these tributaries, Elk Run, Laurel Run, and Abram Creek contributed 65 percent of the total measured net acidity load of 33 tons/day in the North Branch basin. The total mine drainage acidity formed in the basin is estimated to be 70 tons/day based on sulfate loadings measured during 1966-1967.

Eighty-one percent of the total net acidity measured in the stream originated in the Upper Potomac coal field, 2 percent in the Georges Creek field, and 17 percent was unaccounted. Fifty-seven percent of the total measured net acidity originated in the headwaters above the USGS gage at Steyer, Maryland. West Virginia sources contributed 63 percent of the total measured acid load in the North Branch basin. Maryland tributaries added 20 percent.

Based on data from the Maryland Department of Water Resources (1965) and a knowledge of the area, it is estimated that there are in the order of 630 sources of mine drainage in the North Branch basin. There are 469 sources in Maryland alone, including 400 in inactive mines and 69 in active mines (Maryland Department of Water Resources, 1965)

In 1966, a total of 130 miles of stream in the North Branch basin was continuously polluted by mine drainage, and an additional 30 to 40 miles were mildly or intermittently affected. Most of these streams carried a net acid load. There are few sources of natural alkalinity in the region. Shales and sandstones containing coals and fire clays dominate the geology. There is only one limestone stratum in the North Branch basin, and that lies in the Georges Creek watershed.

Biological sampling throughout the North Branch basin revealed, in general, only sparse populations of acid-tolerant benthic organisms. There conditions are attributed to mine drainage pollution.

A detailed discussion of the mine drainage sources in the North Branch basin and their effect on stream quality follows:

A. North Branch Headwaters at Steyer, Maryland

The North Branch was sampled at Kempton, Maryland, approximately two miles downstream from its source. As shown in Figure 35, at Kempton the North Branch discharged 0.2 tons/day net acidity, less than 1 percent of the net acidity contributed in the basin. Fourteen miles downstream from Kempton, at Steyer, Maryland, the net acidity load had increased to 26 tons/day. The acidity measured at Steyer was 82 percent of the total net acidity measured in the North Branch. The three tributaries discussed below discharged 18 tons/day to the North Branch in this reach.

1. Elk Run

Elk Run, a minor tributary in terms of drainage area, contributes more net acidity to the North Branch than any other tribtuary. At its confluence with the North Branch, Elk Run had a pH of 2.8 and a mean net acidity concentration of 1,900 mg/l. The measured flows ranged between 1.7 and 3.3 cfs, but the enormous acid concentration resulted in a mean contribution of 12 tons/day net acidity to the North Branch. This load represents 38 percent of the total measured net acidity in the North Branch. Elk Run's streambed was colored a bright orange, a purplish brick-red, and green (algae) and was covered with a crusted sediment more than a foot thick in many places. The Elk Run sampling stations lies a few hundred yards downstream from a coalyard and mines operated by the Alpine Coal Company.

Three water samples collected at the same site by the West Virginia Division of Water Resources indicated that acid concentrations were roughly an order of magnitude lower than present concentrations as mining operations.

2. Laurel Run

Laurel Run discharged 4.9 tons/day net acidity to the North Branch, 14 percent of the total measured net acid load. Although there are strip mines in the watershed, most of the mine drainage originates in an abandoned underground mine near Kempton. Much of the mine is in West Virginia.

3. Buffalo Creek

Buffalo Creek discharged 1.5 tons/day net acidity to the North Branch, 5 percent of the total measured net acid load in the North Branch basin. Samples were taken a few hundred feet above the confluence with the North Branch at Bayard, West Virginia. The North Branch Coal Company yard is located upstream.

B. North Branch - Steyer, Maryland, to Kitzmiller, Maryland

Thirteen miles downstream from Steyer, at Kitzmiller, Maryland, the acid load in the North Branch was 32 tons/day net acidity, an increase of 6 tons/day over the load at Steyer. The acid load at Kitzmiller equals the total net acidity measured in the North Branch. Below Kitzmiller the net acidity contributions are small and are balanced by natural contributions of net alkalinity. The three tributaries discharging net acidity to the North Branch in this reach are: Stony River (0.8 tons/day), Wolfden Run (0.1 ton/day), and Abram Creek (4.2 ton/day).

1. Stony River

The quality of Stony River is very mildly influenced by mine drainage near Mount Storm, West Virginia, about 5 miles above its confluence with the North Branch. At Mount Storm the river supports trout. The only known contribution of mine drainage to Stony River is from Laurel Run, a small intermittently polluted tributary several miles upstream.

2. Abram Creek

The 4.2 tons/day acidity contributed to the North Branch by Abram Creek is 13 percent of the total measured net acidity in the North Branch basin. The major part of the mine drainage in Abram Creek originates in the headwaters at Bismark, West Virginia. The net acidity load at this point was 1.9 tons/day. Downstream, at Mt. Pisgah, West Virginia, Abram Creek carried 4.5 tons/day net acidity, a load substantially equal to that discharged to the North Branch. Two tributaries, Glade Run and Emory Creek, discharged an estimated total of 1 ton/day net acidity below Mt. Pisgah, but some neutralization occurs before the water reaches the North Branch.

C. North Branch - Kitzmiller, Maryland, to the Savage River

Just above the mouth of the Savage River, fourteen miles downstream from Kitzmiller, Maryland, the North Branch carried 31 tons/day net acidity, a decrease from the acidity loading at Kitzmiller. Measured contributions of net acidity in the Kitzmiller-Savage River reach amounted to 2 tons/day, indicating that neutralization occurs in this reach. The North Branch is grossly polluted at Kitzmiller. Measured pH values were less than 3.5 and benthic sampling revealed no organisms. The four tributaries discharging net acidity to the North Branch between Kitzmiller and the Savage River are:

1. Three Forks Run

Three Forks Run discharged 1.0 tons/day net acidity to the North Branch, 3 percent of the total measured net acidity load in the North Branch basin. It is grossly polluted by runoff from mines and possibly from spoil piles in the watershed. In August 1966, a pH of 1.8 was measured in Three Forks Run.

2. Deep Run

Deep Run discharged an insignificant net acidity load to the North Branch, less than 1 percent of the total measured net acidity in the North Branch basin. Benthic sampling indicated sparse populations of clean-water organisms. Deep Run is mildly polluted by mine drainage.

3. Elklick Run

Elklick Run was sampled once, during April 1967, just above its confluence with the North Branch. The stream lies in Maryland about a mile downstream from Shaw, West Virginia. Elklick Run contributed 0.3 tons/day net acidity to the North Branch, about 1 percent of the total measured load in the watershed.

4. Piney Swamp Run

Piney Swamp Run contributed 1.3 tons/day net acidity to the North Branch, or 4 percent of the total measured net acidity in the watershed. Samples were taken at Hampshire, West Virginia, a few hundred feet above the confluence with the North Branch. The Hampshire station lies at the foot of an active mining area operated by Masteller Coal Company. Above these operations, the flow in Piney Swamp Run is only about 15 percent of the flow at the mouth and stream quality is considerably better than at Hampshire.

D. North Branch - Savage River to Cumberland, Maryland

The acidity loading of 31 tons/day carried by the North Branch just above the mouth of the Savage River augmented slightly by acidity discharged from Georges Creek, but alkalinity contributed by the West Virginia Pulp and Paper Company Mill at Luke, by the Upper Potomac River Commission Waste Treatment Plant at Westernport, and by other sources largely neutralizes the acidity in the North Branch. This neutralization is reflected by the increase in average pH from about 4.0 just above the mouth of the Savage River to about 6.5 at Keyser 7-1/2 miles downstream.

No mine drainage acidity enters the North Branch below Georges Creek, but some mine drainage pollution is discharged into the North Branch by Wills Creek at Cumberland in the form of hardness and sulfates. Tributary and mill effects are discussed below in the order in which they occur:

1. Savage River

The quality of the Savage River is mildly degraded by mine drainage in a one-mile reach from its mouth to Aaron Run. In this reach, Savage River maintains about 5 mg/l net alkalinity. This results in a discharge of 0.8 tons/day net alkalinity, which is not adequate to appreciably reduce the net acidity load in the North Branch although some reduction in acid concentration occurs by dilution. The Savage River is regulated to maintain a minimum flow of 93 cfs in the North Branch at Luke. Aaron Run, the only contributor of mine drainage to Savage River, is badly polluted. Upstream from Aaron Run, the water in Savage River is of excellent quality.

2. West Virginia Pulp and Paper Company

Until recently, spent process lime discharged from the West Virginia Pulp and Paper Company Mill at Luke neutralized the acid load in the North Branch. Since late 1966 this spent lime has been reprocessed within the plant. As a result, the acidity that originates upstream from the mill is no longer completely neutralized.

The company withdraws more than 20 mgd of process water from the North Branch at Luke. This reduces the acid load by about 8 tons/day or about 25 percent. Waste is returned downstream at Westernport, except for boiler house, evaporator, and flyash discharges at Luke. These discharges have some neutralizing effect, but will be discontinued soon.

During April 1967, the Maryland Department of Water Resources monitored the pH of the North Branch below the West Virginia Pulp and Paper Company mill. The pH alternated between 3.5 and 4.5, depending presumably on intermittent discharges of alkaline waste. After the waste discharges are stopped, the pH will probably not rise above 4.0.

3. Georges Creek

Georges Creek, which enters the North Branch at Westernport, Maryland, contributes 0.6 tons/day net acidity, or 2 percent of the total measured net acidity in the North Branch basin. Most of the acidity in Georges Creek enters directly from deep mines that line the sides of the valley.

4. Upper Potomac River Commission Waste Treatment Facility

This waste treatment plant is located on the downstream side of Westernport, Maryland. About 95 percent of the plant's load consists of process wastes from the West Virginia Pulp and Paper Company Luke Mill. The UPRC plant discharges an average of 20 mgd, which contributes a load of 8.5 tons/day net alkalinity to the North Branch. This is equivalent to 27 percent of the total measured net acidity in the North Branch basin. Three miles downstream from the UPRC plant, at Keyser, West Virginia, pH values between 6 and 7 were observed in the North Branch early in 1967.

5. Wills Creek

Wills Creek, which enters the North Branch in downtown Cumberland, Maryland, does not contribute acidity to the North Branch, although mine drainage residual effects (high hardness and sulfate concentrations) are apparent in chemical data. Braddock Run and Jennings Run, tributaries that enter Wills Creek from the Georges Creek coal field to the west, are degraded by mine drainage. Braddock Run receives the discharge from the Hoffman Tunnel, a drainage tunnel bored in the early 1900's to drain deep mines in Georges Creek basin.

At Cumberland, Maryland, high hardness and sulfate concentrations are apparent in North Branch chemical data, but acid conditions have not been observed.

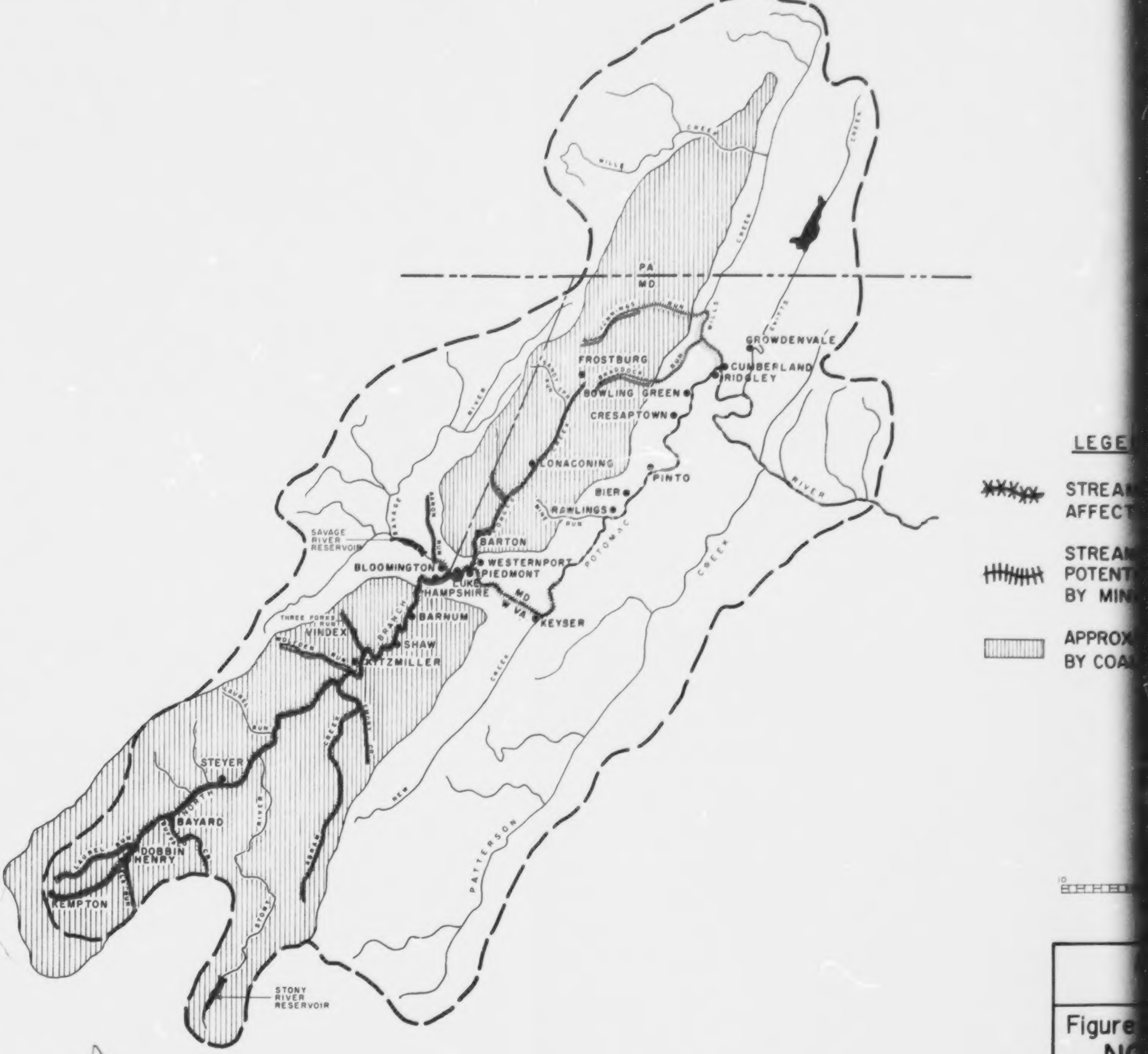
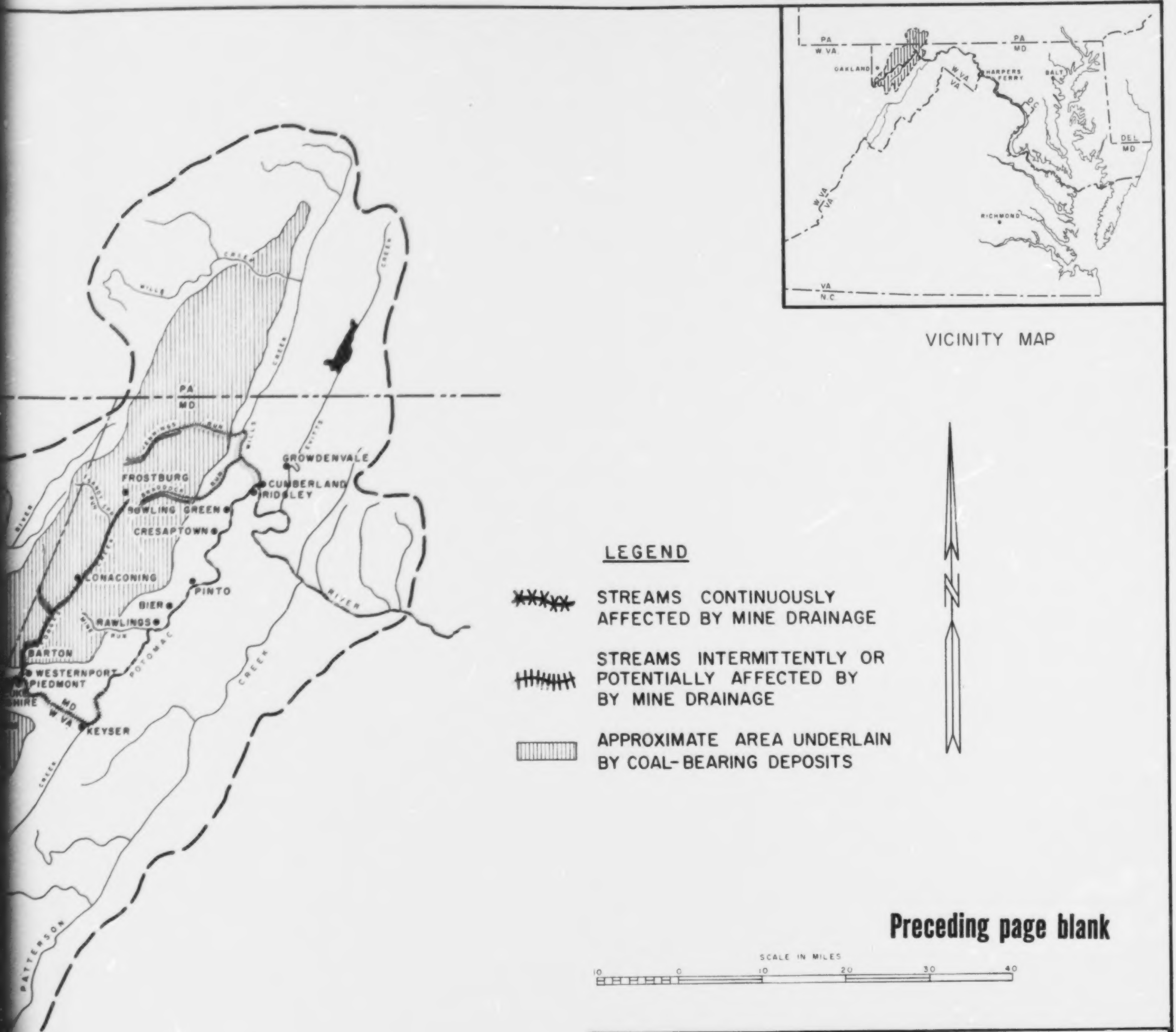

PA
MD
FROSTBURG
CUMBERLAND
RIDGLEY
CROWDENVALE
BOWLING GREEN
CRESAPTOWN
LONACONING
PINTO
BIER
RAWLINGS
BARTON
WESTERNPORT
PIEDMONT
BLOOMINGTON
LUKE
HAMPSHIRE
BARNUM
VINDEX
SHAW
KITZMILLER
STEYER
BAYARD
DOBBIN
HENRY
KEMPTON
KEYSER
MD
W VA
SAVAGE RIVER RESERVOIR
STONY RIVER RESERVOIR
THREE FORKS RUN
SAVAGE RIVER
POTOMAC
RIVER
WILLS CREEK
PATTERSON CREEK
NEW CREEK
LAUREL RUN
STONY RIVER
ABRAM CREEK
GEORGES CREEK
BRADDOCK RUN
JENNINGS RUN
EVITTS CREEK
WINNS RUN
NORTH BRANCH
LEGE
STREAM AFFECT
STREAM POTENT BY MIN
APPROX BY COA

Figure
NO

FEDER

A


VICINITY MAP
PA
W VA
PA
MD
OAKLAND
HARPERS FERRY
BALT
W VA
VA
DEL
MD
RICHMOND
VA
N.C.
PA
MD
WILLS
CREEK
JENNINGS RUN
BRADDOCK RUN
GROWDENVALE
FROSTBURG
CUMBERLAND
RIDGLEY
BOWLING GREEN
CRESAPTOWN
LONACONING
PINTO
BIER
RAWLINGS
BARTON
WESTERNPORT
PIEDMONT
MD
W VA
KEYSER
POTOMAC
RIVER
CREEK
PATTERSON
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
N
SCALE IN MILES
10
0
10
20
30
40

Preceding page blank

APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 34
NORTH BRANCH POTOMAC RIVER BASIN

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

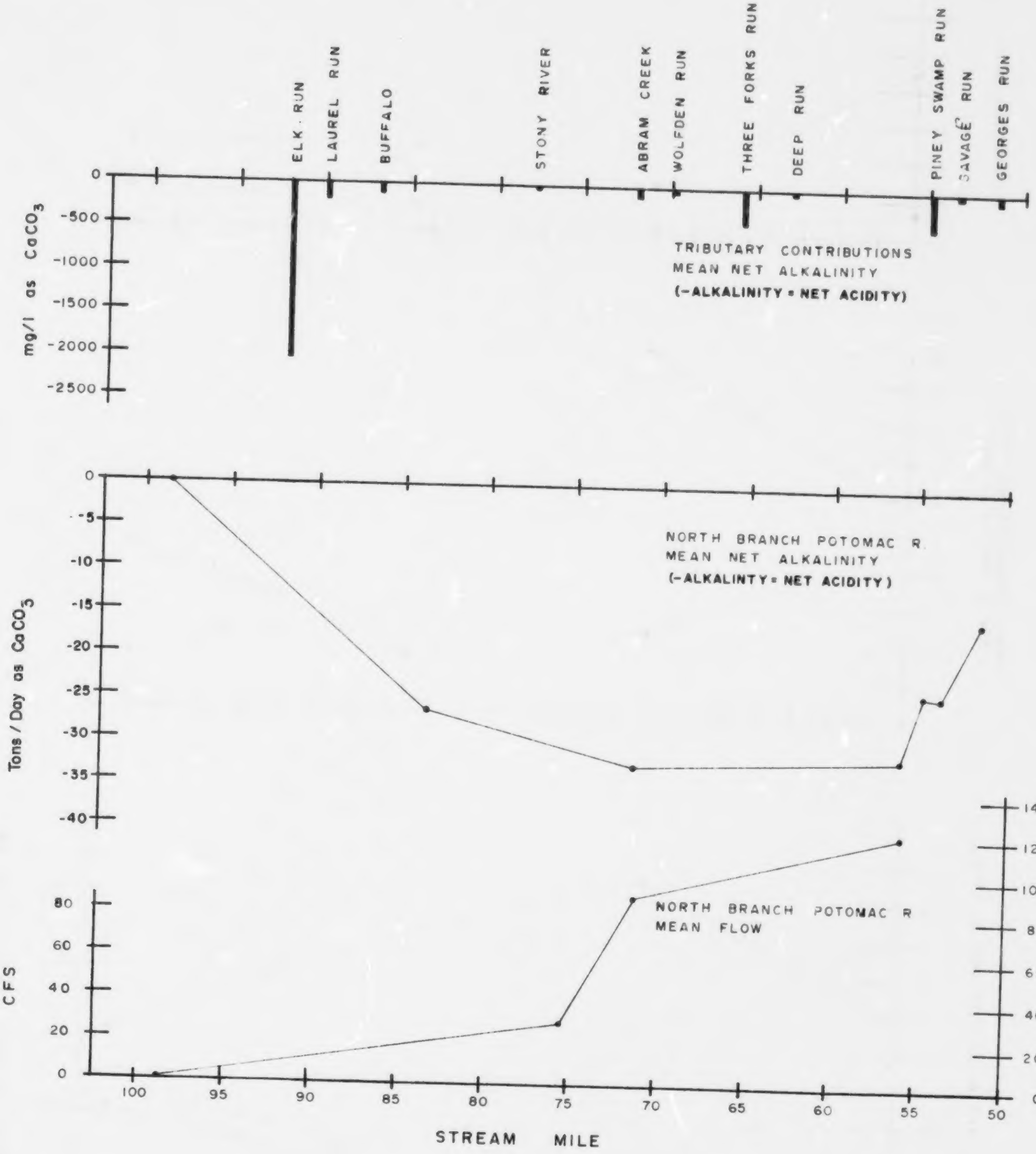


FIGURE 35

PROFILE OF FLOW, NET ALKALINITY OF NORTH BRANCH POTOMAC RIVER AND TRIBUTARY CONTRIBUTIONS OF NET ALKALINITY

Preceding page blank

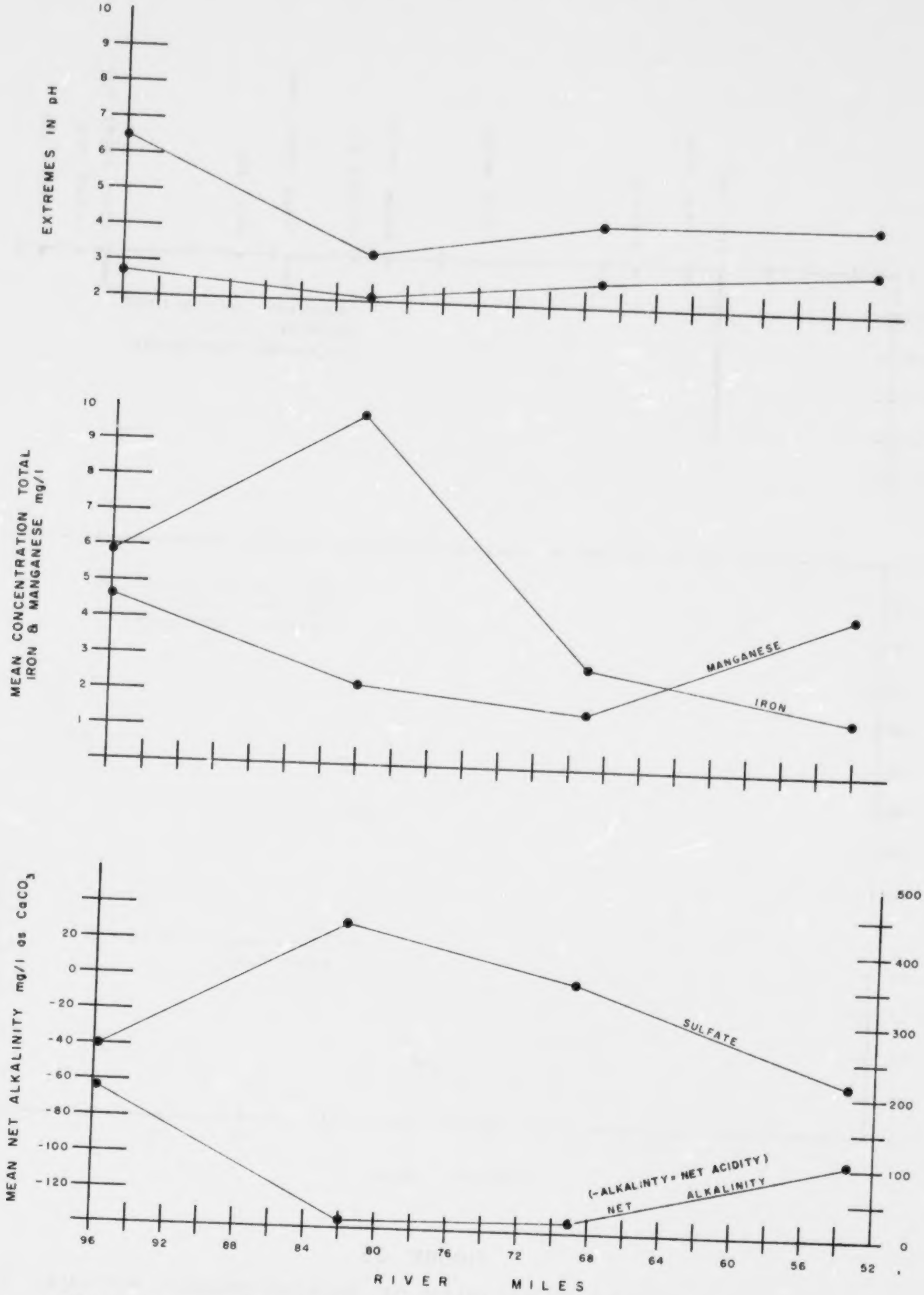


FIGURE 36 PROFILE OF pH, MANGANESE, IRON & SULFATE CONCENTRATION AND NET ALKALINITY

NORTH BRANCH POTOMAC RIVER

Allegheny River Basin

Description

The Allegheny River rises near Coudersport in Potter County, Pennsylvania (Fig. 37). It flows westward and then northward into New York then turns south near Salamanca, New York, and flows southwestward through Pennsylvania. It joins the Monongahela River at Pittsburgh to form the Ohio River. The total length of the Allegheny River is about 325 miles.

The Allegheny River basin embraces about 11,730 square miles in western New York and Western Pennsylvania all of which is within the Appalachian Region. It is about 175 miles long on a north-south axis and its maximum width is about 130 miles. About 1,965 square miles of New York and 9,765 square miles of Pennsylvania are in the watershed. Adjacent are the Great Lakes-St. Lawrence River basin on the north, the Susquehanna River basin on the east, the Monongahela River basin on the south, and the Beaver River basin or direct drainage to the Ohio River on the west. Principal tributaries to the Allegheny are the Kiskiminetas and Clarion Rivers, and Mahoning, Redbank, French, Oil, Tionesta, and Conewango Creeks.

The Allegheny River basin is in the southern New York and Kanawha sections of the Appalachian Plateau's physiographic province. The southern New York section represents a mature glaciated plateau of moderate relief. The Kanawha section represents a mature unglaciated plateau of fine texture with moderate to strong relief.

About 25 percent of the topography of the basin has been modified by the advance of the last continental ice sheets. The line of farthest advance crosses the northwestern part of the region running from just west of Franklin, Pennsylvania, to just east of Jamestown, New York. The topography of the glaciated area is generally that of rolling plains with gentle slopes. Many lakes and swamps have been formed on the glacial deposits because the post-glacial drainage has not had time to develop a significant degree of integration. South and east of the glacial advance, the topography displays moderate to strong relief. In the mountain upland and high plateau areas of the basin, the land is highly dissected by its drainage. For example, the Conemaugh River and Loyalhanna Creek gorges are over 1,000 feet deep. The highest points in the upland areas are above 2,500 feet in elevation.

Bituminous coal reserves are present in 14 of the 19 Pennsylvania counties that are wholly or partly in the basin, amounting to some 57 percent of the total basin land area (Figure 37). Coal has been mined in all but one of these 14 counties, with Armstrong, Clarion, and Indiana having been the principal producing counties. The recoverable coal reserve in the Allegheny River basin portion of these counties is estimated to be nearly 11 billion tons. There are no coal deposits in the New York portion of the basin.

By 1877, bituminous coal mining in western Pennsylvania had evolved into a significant industry, producing 1.3 million tons in that year. From this early beginning, production of coal in western Pennsylvania has not fallen under 50 million per year since 1894. A peak annual production of 177 million tons was reached in 1918. Production in the Allegheny River basin in 1965 was 30 million tons.

Mine Drainage Sources and Their Effect on Stream Quality

Significant mine drainage stream pollution exists in 14 Pennsylvania counties of the basin. Nearly all of the 979 miles of continuously affected and 87 miles of intermittently affected streams are found in that portion of the watershed south of a general east-west line between Franklin, Pennsylvania, Venango County and St. Marys, Pennsylvania in Elk County. Stream pollution from mine drainage is particularly acute in terms of numbers of streams and total length of streams affected in Armstrong, Cambria, Clarion, Indiana, Somerset, and Westmoreland Counties. Table 5 gives the miles of polluted streams by watershed.

Table 5 - Lengths of Streams Significantly Affected by Mine Drainage, Allegheny River Basin

	Drainage Area (square miles)	Continuously Polluted (miles)	Intermittently Polluted (miles)	Total
Allegheny River	11,733	30		30
Minor Tributaries		281	58	339
Kiskiminetas River	1,892	24		24
Tributaries		40	5	45
Conemaugh River	1,376	48		48
Tributaries		310	6	316
Loyalhanna Creek	300	21		21
Tributaries		31		31
Clarion River	1,232	21		21
Tributaries		173	18	191
		979	+ 87	= 1,671

Field studies have been made jointly by the Pennsylvania Department of Health and FWPCA to locate and characterize individual sources of mine drainage pollution in the Clarion and Kiskiminetas River watersheds. The results of these studies are summarized in the table on the following page.

Since 85 percent of the acidity formed in the basin originates in the Clarion and Kiskiminetas River watersheds. These watersheds contain most of the mine drainage sources in the Allegheny basin. It is clear that abandoned underground mines and reclaimed surface-mined lands are the major sources of pollution. Active underground mines are significant in particular in the Blacklick Creek watershed.

A significant fact that is true in nearly all cases in the inventories that have been carried out is exemplified by the survey results in the Clarion River basin. In this area, 10 percent of the sources of acid discharge were found to contribute 70 percent of the acid drainage. In this and many other cases, control over a relatively small percentage of major sources will return the streams involved to a satisfactory condition.

It is estimated that an average of 2,400 tons/day of acidity are formed in the Allegheny basin and that 1,600 tons/day of net acidity enters streams in the basin. The estimate of total acidity formed is based on average sulfate loadings in the Allegheny River at Kittanning and in the Kiskiminetas River at Leechburg (Figures 38 and 39). Table 6 lists the streams in the Allegheny basin that carried more than 5 tons/day of net acidity during the sampling period in 1966.

Much of the acidity discharged to streams in the Allegheny basin is neutralized before it reaches the lower Allegheny. An average of only 150 tons/day of unneutralized acidity reached Pittsburgh during a 1965-1966 study (Shapiro and others, 1966). Water quality records show that acid conditions in the lower Allegheny River are particularly acute during periods of low flow when the percentage contribution of flow to the main stem by the Kiskiminetas is greater than normal. When roughly 30 percent of the flow in the Allegheny is from the Kiskiminetas River, fish kills are expected. One million fish were killed in the Allegheny River below the Kiskiminetas due to acid conditions during the period August 19-23, 1966.

A detailed discussion of the mine drainage sources in the Allegheny basin, and their effect on stream quality follows.

Mine Drainage Sources and Net Acidity Contributions Allegheny River Basin

Area / Sub-Area	Active Operations						Inactive Operations								Total Sources	
	Underground Mines		Surface Mines		Other Sources		Underground Mines		Surface Mines		Combination Surface and Underground Mines		Other Sources			
	No. of Sources	Net Acidity	No. of Sources	Net Acidity	No. of Sources	Net Acidity	No. of Sources	Net Acidity	No. of Sources	Net Acidity	No. of Sources	Net Acidity	No. of Sources	Net Acidity	No. of Sources	Net Acidity
Kiskiminetas River																
Conemaugh River							24	27,786	4	1,734	1	162	6	6,578	35	36,260
Stony Creek	7	5,954	4	475	1	84	117	69,188	32	2,468	21	3,783	2	926	184	82,878
Little Conemaugh River	3	1,716	1	33			55	158,639	17	2,137	6	1,942	15	6,350	97	170,817
Two Lick Creek	5	501					75	20,479	44	2,605	28	13,700	22	7,329	174	34,614
Blacklick Creek	14	134,450					55	71,534	39	2,004	27	9,421	25	55,624	160	273,033
Loyalhanna Creek							29	57,050	7	938	9	588	5	2,883	50	61,459
Minor Tributaries	2	3,365					26	19,269	12	1,337	15	6,493	9	22,668	64	53,132
(Sub-Total)	31	145,986	5	508	1	84	381	423,945	155	13,223	107	26,089	84	102,358	764	712,193
Allegheny River																
Clarion River																
Toby Creek (Elk & Jefferson Cos., Pa.)	3	103					62	21,820	26	1,214	28	14,287			119	37,424
Deer Creek					2	384	17	3,621	15	1,197	11	814	12	4,214	60	10,840
Licking Creek	1	27					18	1,572	106	2,656	5	1,380	1	667	131	6,302
Toby Creek (Clarion Co.)							26	4,324	43	75,403			14	1,439	83	81,166
Mill Creek									15	6,704			4	91	19	6,795
Piney Creek			3	1,281			22	1,843	35	5,469	13	2,305	6	78	79	10,976
(Sub-Total)	4	130	3	1,281	2	384	145	33,180	240	92,643	57	18,786	37	6,489	491	153,503
Total Clarion & Kiskiminetas Rivers	35	146,116	8	1,789	3	468	526	457,125	395	105,866	164	44,875	121	108,847	1,255	865,696

Table 6 - Net Acidity Loads, Allegheny River Basin

Sampling Station Number	Stream	Net Acidity Load (tons/day)
519	Little Toby Creek (tributary to Toby Creek, Elk County)	8.4
518	Toby Creek at the Clarion River (Elk County)	7.5
517	Mill Creek at the Clarion River	8.5
516	Toby Creek at the Clarion River (Clarion County)	24
515	Piney Creek at the Clarion River	9.6
514	Deer Creek at the Clarion River	6.9
513	Licking Creek at the Clarion River	8.4
524	Clarion River at Mouth	63
558	Pine Run at Mahoning Creek	6.1
560	Crooked Creek at Mouth	17
493	Dark Shade Creek	12
574	Two Lick Creek	38
577	North Branch Blacklick Creek	88
573	Blacklick Creek at the Kiskiminetas R.	213
494	Shade Creek	13
570	Loyalhanna Creek at the Kiskiminetas River	57
569	Blacklegs Creek at Mouth	5
579	Conemaugh River at USGS Gage at Seward	86
567	Kiskiminetas River at Vandergrift, Pennsylvania	494
566	Allegheny River at Natrona, Pennsylvania	245

Although the Allegheny River receives small amounts of mine drainage from minor tributaries in Venango County, the first mine drainage of any dimension is received from the Clarion River in western Clarion County. The Clarion River discharged an average of 63 tons/day net acidity to the Allegheny River during the 1966 survey.

In the moderately polluted upper Clarion River basin, mine drainage enters the headwaters of East Branch Clarion River. At sampling station 522 below the East Branch Reservoir (Fig. 37, Table 7) the pH during the sampling period ranged from 5.5 to 6.6 and the net acidity load was 4 tons/day. The main stem Clarion receives only minor drainage increments below the East Branch Reservoir until the entry of Toby Creek in southern Elk County. During the sampling period, Toby Creek added an acidity load of 7.5 tons/day to the Clarion and had a pH range of 3.6 to 4.1 (sta. 518).

Very little mine drainage enters the Clarion River between Toby Creek and station 523 on the river below Cooksburg, Pennsylvania. At station 523, the pH ranged from 5.7 to 6.7 and the average alkalinity slightly exceeded the average acidity. Total mineralization of the water was relatively low.

The Clarion River is grossly polluted by mine drainage in its lower section. At the Cooksburg station (Sta. 523), the Clarion was found to have a pH range of 5.7 to 6.7. At its mouth, the Clarion carried an acid load of 63 tons/day and exhibited a pH range of 4.1 to 5.3, during the survey. Between Cooksburg and the mouth, the Clarion River receives mine drainage from a number of very poor quality tributaries. The principal contributing tributaries in this reach and their acid loads are presented in the following table.

Station Number:	Stream:	Location:	pH Range	Average Net Acidity Load (tons/day)
517	Mill Creek	Mouth	2.9-3.2	8.5
518	Toby Creek	Mouth	2.8-3.1	24
515	Piney Creek	Mouth	3.4-4.0	9.6
514	Deer Creek	Mouth	3.2-3.4	6.9
513	Licking Creek	Mouth	2.6-3.1	8.4

The Clarion River watershed contains over 200 miles of mine drainage polluted streams. The principal problem areas are acid tributary watersheds in the lower basin in Clarion County. The acidity load received by the Clarion River in this reach is about 57 tons/day.

At Parker Bridge, about two and one-half miles below the mouth of the Clarion River (Sta. 565), the Allegheny had assimilated the large acidity load from the Clarion. The minimum pH at this location was 6.4, and the alkalinity was consistently greater than the acidity. Between the Clarion and Kiskiminetas Rivers, the Allegheny River receives significant loads of mine drainage indicators such as sulfate and hardness from Redbank, Mahoning, and Crooked Creeks. An acidity load of 17 tons/day is discharged by Crooked Creek (Sta. 560) Redbank and Mahoning Creeks are essentially neutral at their mouths (Stas. 525 & 557).

Thirty miles above Pittsburgh, the Kiskiminetas River enters the Allegheny. During the 1966 survey it discharged a massive load of 494 tons/day of acidity, as measured at Vandergrift, Pennsylvania. The pH of the stream ranged from 3.0 to 3.6 and the alkalinity was depleted throughout the survey. Long term water quality records (Fig. 39) show that an average of about 1,700 tons/day of acidity are formed in the Kiskiminetas River basin 900 tons/day of which are discharged to the Allegheny River as acidity.

Within the Kiskiminetas watershed there are about 485 miles of streams polluted by mine drainage. A large number of streams are acid even in the upper headwater areas of Somerset and Cambria Counties. The Conemaugh River above Johnstown carried an acidity load of 25 tons/day originating from the watersheds of both the North and South Branches (Sta. 581).

Stony Creek, which enters the Conemaugh River at Johnstown, drains 466 square miles of the southern portion of the headwaters area and contains over 100 miles of acid streams. The principal tributaries of Stony Creek are polluted by mine drainage. Shade Creek carried an acidity load of 13 tons/day (Sta. 494). Additional acidity entering the Conemaugh between Johnstown and station 579 raised the net acidity load in the river to 80 tons/day.

Blacklick Creek and many of its tributaries are acid over their entire length. The Blacklick Creek watershed contains over 100 miles of drainage polluted streams. The pH at the mouth of Blacklick Creek ranged from 2.5 to 2.9 and the total acidity concentration from 452 to 897 mg/l (Sta. 573). The acidity load of 213 tons/day discharged from Blacklick Creek was 43 percent of the acid load discharged by the Kiskiminetas River.

An acidity load of 88 tons/day was measured on the North Branch Blacklick Creek at Ripton in Cambria County (Sta. 577). Although the watershed above this point represents only 14 percent of the Blacklick Creek watershed, 42 percent of the total acidity load of Blacklick Creek was measured here. The load at this station is about 20 percent of that measured in the Kiskiminetas at Vandergrift. Two Lick Creek discharged an acidity load of 38 tons/day to Blacklick Creek (Sta. 574).

The Conemaugh River below Blairsville (Sta. 575) carried an acidity load of 400 tons/day, contained no alkalinity, and exhibited a pH range of 2.9 to 3.3. Continuing downstream, the Kiskiminetas River is formed where the Conemaugh River and Loyalhanna Creek converge just above the Armstrong-Indiana County line. Loyalhanna Creek is an acid stream over much of its length and contributed a net acidity load of 57 tons/day. The pH ranged from 3.3 to 4.7 and the alkalinity was completely depleted (Sta. 570).

From the origin of the Kiskiminetas River to its mouth there are a number of small acid contributing tributaries. The largest of these is Blacklege Creek which contained a net acidity load at its mouth of 5 tons/day (Sta. 569).

During the 1966 water quality survey, the Kiskiminetas River at Vandergrift contained an average manganese concentration of 23.2 mg/l. High manganese concentrations (9-23.2 mg/l) were found at all stations in the Conemaugh and Kiskiminetas Rivers below Johnstown. Manganese concentrations in tributaries to the Conemaugh-Kiskiminetas main stem averaged about one-tenth of the main stem concentrations. The higher manganese levels in the main stem below Johnstown are probably due to discharges from the steel industry in the Johnstown area.

The Conemaugh-Kisiminetas River is an acid stream over its entire length and the river system is grossly polluted by coal mine drainage. Acid-sterile streams in this watershed are the rule and not the exception.

Although the Allegheny River possessed adequate dilution and neutralizing capability to assimilate mine drainage waters received above the mouth of the Kiskiminetas River, the water quality is significantly degraded below this point. The Allegheny River at Natrona, Pennsylvania (Sta. 566) carried an average net acidity load of 245 tons/day and had a pH range of 4.0 to 6.8. The total acidity concentration exceeded the alkalinity concentration during two thirds of the survey period. However, the acidity concentration was generally below 30 mg/l.

Table 7 - Water quality data, Allegheny River basin

Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Total Manganese (mg/1)	Total Aluminum (mg/1)	Flow (cfs)
490	Min.	7	6.5	0.0	13.0	76.0	34.0	0.0	0.1	0.0	8.4
	Max.		7.1	12.0	32.0	172.0	145.0	2.0	0.7	2.5	70.0
	Avg.			6.7	19.6	136.1	106.0	0.6	0.4	1.1(6)*	19.9
492	Min.	7	6.2	3.0	5.0	7.0	4.0	0.0	0.0	0.0	1.5
	Max.		7.8	10.0	15.0	60.0	25.0	1.0	0.2	2.1	83.0
	Avg.			6.7	9.9	34.0	12.9	0.2	0.1	0.5(6)	17.7
493	Min.	7	2.8	107.0	0.0	148.0	48.0	7.5	0.2	10.4	9.6
	Max.		4.4	445.0	0.0	363.0	825.0	73.2	8.2	30.8	50.0
	Avg.			270.3	0.0	260.3	501.4	46.7	5.1	22.3(6)	20.5
494	Min.	7	2.7	53.0	0.0	86.0	120.0	6.7	0.1	2.5	9.0
	Max.		3.8	255.0	0.0	332.0	490.0	22.1	6.0	30.8	120.0
	Avg.			148.0	0.0	184.9	310.7	12.0	3.4	15.8(6)	49.6
495	Min.	7	6.5	0.0	13.0	94.0	71.0	0.4	0.0	0.3	5.0
	Max.		7.4	25.0	33.0	502.0	475.0	2.2	0.4	3.6	65.0
	Avg.			9.0	22.9	297.9	284.4	1.3	0.2	2.1(6)	18.9
499	Min.	7	6.3	2.0	13.0	60.0	80.0	0.0	0.0	0.0	5.4
	Max.		7.2	12.0	43.0	285.0	135.0	1.0	0.2	2.9	116.0
	Avg.			7.1	27.3	143.0	106.8(6)	0.3	0.1	1.2(6)	26.2
501	Min.	7	3.2	9.0	0.0	60.0	36.0	3.1	0.0	1.1	10.5
	Max.		6.0	105.0	12.0	127.0	194.0	12.2	0.8	8.4	40.0
	Avg.			36.9	3.0	85.6	108.3	6.4	0.3	3.3(6)	22.7
503	Min.	6	7.0	0.0	39.0	68.0	15.0	0.1	0.2	0.7	170.0
	Max.		7.9	14.0	73.0	152.0	25.0	1.0	0.3	3.9	600.0
	Avg.			7.0	55.5	110.7	19.2	0.5	0.3	1.6	380.0
504	Min.	6	6.7	0.0	35.0	337.0	5.0	0.0	0.0	0.7	7.0
	Max.		6.9	19.0	62.0	838.0	30.0	4.8	0.5	30.2	23.8
	Avg.			12.5	46.7	562.7	16.5	1.5	0.2	9.7	15.2

Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Total Manganese (mg/l)	Total Aluminum (mg/l)	Flow (cfs)
506	Min.		7.1	0.0	46.0	75.0	5.0	0.3	0.2	0.1	470.0
	Max.	6	7.4	18.0	81.0	135.0	30.0	1.4	0.5	6.7	1900.0
	Avg.			7.5	65.2	99.5	19.0	0.8	0.3	2.4	969.2
508	Min.		6.8	0.0	15.0	25.0	9.0	0.1	0.0	0.0	6.0
	Max.	6	7.8	13.0	40.0	59.0	35.0	0.3	0.2	2.0	38.0
	Avg.			7.0	26.8	36.7	22.3	0.2	0.1	0.8	18.4
509	Min.		7.6	0.0	46.0	68.0	15.0	0.4	0.0	1.0	740.0
	Max.	6	8.7	9.0	74.0	132.0	70.0	1.0	0.5	2.8	3280.0
	Avg.			4.7	60.7	90.3	33.5	0.7	0.2	1.9	1752.7
510	Min.		7.1	0.0	24.0	59.0	20.0	0.0	0.0	0.0	8.0
	Max.	6	7.7	12.0	52.0	84.0	55.0	0.5	0.3	2.1	28.0
	Avg.			5.5	35.3	68.7	45.3	0.3	0.1	1.1	20.0
511	Min.		4.8	10.0	3.0	256.0	150.0	0.3	3.6	1.5	10.8
	Max.	6	7.5	49.0	16.0	290.0	260.0	4.3	5.8	10.5	16.0
	Avg.			24.8	7.3	278.0	219.2	2.0	4.7	4.4	13.6
512	Min.		4.4	18.0	0.0	81.0	50.0	0.5	1.9	1.4	19.6
	Max.	6	6.4	39.0	10.0	120.0	110.0	0.8	2.9	4.6	186.0
	Avg.			25.5	3.7	100.8	90.8	0.6	2.3	2.9	53.3
514	Min.		3.2	101.0	0.0	134.0	140.0	1.1	7.2	4.9	14.5
	Max.	6	3.4	157.0	0.0	245.0	390.0	14.8	11.4	16.7	24.0
	Avg.			134.0	0.0	188.7	280.8	4.8(5)	8.9(5)	11.6(5)	19.3

Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Total Manganese (mg/l)	Total Aluminum (mg/l)	Flow (cfs)
515	Min.		3.4	72.0	0.0	268.0	105.0	0.7	11.0	2.8	1.0
	Max.	6	4.0	218.0	0.0	340.0	450.0	4.8	17.8	25.5	90.0
	Avg.			140.0	0.0	288.8	342.5	3.1	14.0	12.2	24.3
516	Min.		2.8	735.0	0.0	276.0	350.0	79.2	12.0	67.2	3.0
	Max.	6	3.1	1226.0	0.0	552.0	1900.0	144.0	60.0	139.4	15.0
	Avg.			969.7	0.0	414.7	964.2	110.4(3)	38.0	108.5(4)	10.0
517	Min.		2.9	187.0	0.0	69.0	165.0	1.4	20.2	4.0	5.1
	Max.	6	3.2	465.0	0.0	460.0	775.0	18.0	29.3	27.4	17.5
	Avg.			279.7	0.0	337.0	385.0	10.6	26.0	15.0	11.8
518	Min.		3.6	62.0	0.0	221.0	140.0	0.2	5.4	6.1	9.5
	Max.	6	4.1	236.0	0.0	313.0	440.0	1.2	13.8	12.6	54.9
	Avg.			125.7	0.0	271.8	285.8	0.8	7.8	9.8	28.8
519	Min.		3.0	132.0	0.0	300.0	150.0	0.4	9.6	2.0	8.2
	Max.	6	3.4	2840.0	0.0	4160.0	950.0	60.1	38.0	36.0	20.3
	Avg.			651.8	0.0	1032.8	431.7	13.3	15.8	18.0	14.6
522	Min.		5.5	10.0	2.0	20.0	23.0	0.1	0.5	0.2	121.0
	Max.	6	6.6	18.0	7.0	36.0	365.0	0.2	0.9	1.5	170.0
	Avg.			13.5	3.3	24.3	96.2	0.2	0.8	1.0	147.8
523	Min.		5.7	1.0	10.0	50.0	15.0	0.1	0.2	0.8	232.0
	Max.	6	6.7	22.0	18.0	98.0	75.0	2.6	0.5	6.6	335.0
	Avg.			13.3	13.5	86.0	55.8	1.1	0.3	3.7	286.3
524	Min.		4.1	25.0	0.0	100.0	90.0	0.2	2.3	1.9	68.0
	Max.	6	5.3	40.0	4.0	158.0	210.0	1.4	4.4	7.5	2000.0
	Avg.			32.7	2.0	113.8	117.2	0.7	3.0	4.5	761.3

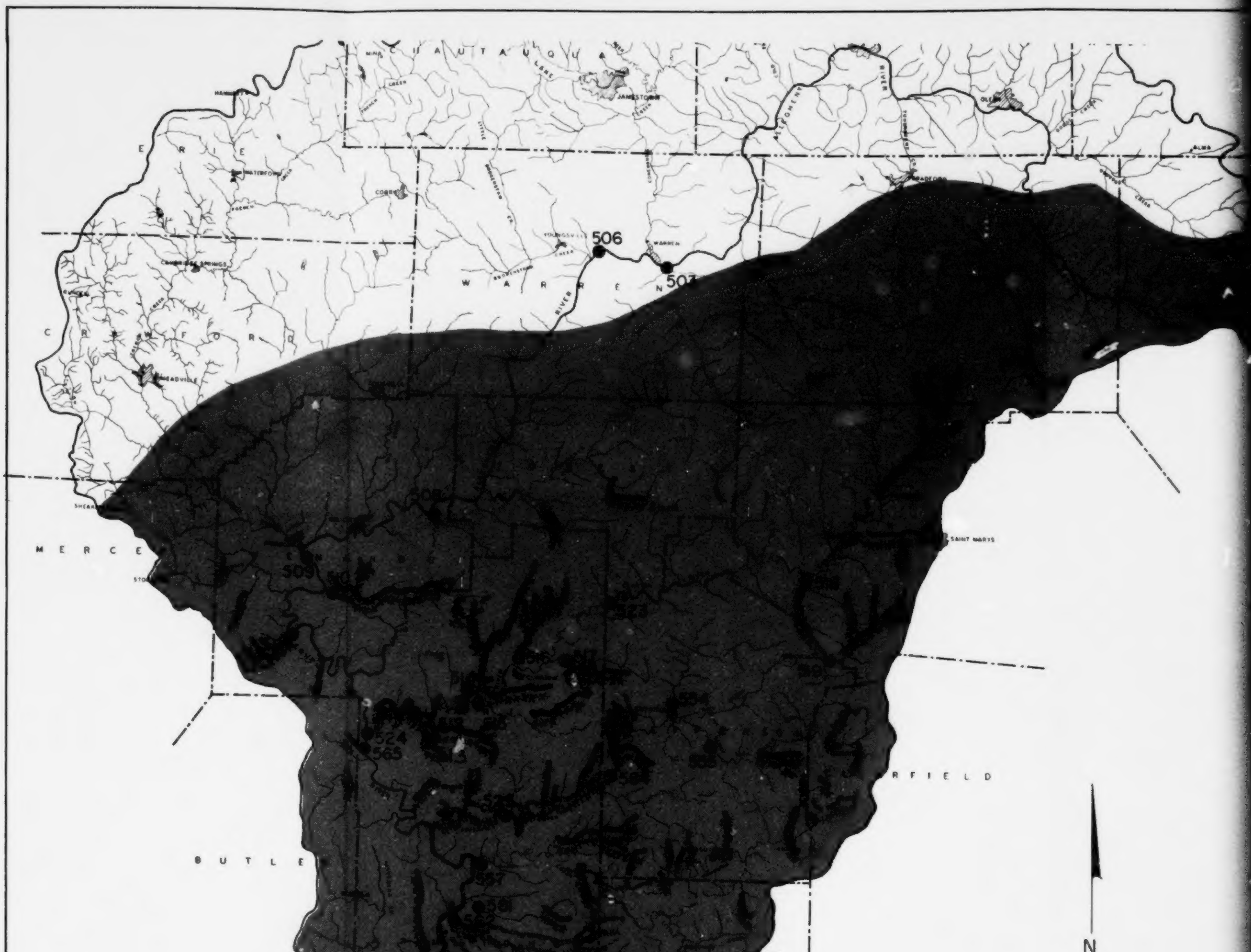
Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Total Manganese (mg/l)	Total Aluminum (mg/l)	Flow (cfs)
525	Min.		6.4	9.0	6.0	155.0	45.0	0.2	0.0	0.9	44.0
	Max.	6	7.2	19.0	17.0	240.0	215.0	1.2	1.0	5.8	128.0
	Avg.			13.0	11.8	183.8	159.2	0.5	0.5	2.2	85.3
554	Min.		6.4	0.0	35.0	20.0	6.0	0.5	0.0	0.4	6.5
	Max.	6	7.4	18.0	70.0	62.0	35.0	1.4	0.2	5.0	17.7
	Avg.			6.8	51.8	35.7	17.7	0.8	0.1	1.5	11.9
555	Min.		6.3	0.0	8.0	90.0	110.0	0.3	0.0	1.0	12.0
	Max.	6	7.4	18.0	40.0	149.0	145.0	0.4	0.3	1.9	38.0
	Avg.			10.0	21.8	127.7	130.8	0.4	0.1	1.3	24.3
557	Min.		6.6	1.0	11.0	120.0	120.0	0.0	0.1	0.2	95.0
	Max.	6	7.0	15.0	36.0	215.0	195.0	0.7	0.7	3.2	300.0
	Avg.			9.5	21.2	158.2	157.0(5)	0.3	0.3	1.1	193.7
558	Min.		2.8	97.0	0.0	207.0	340.0	2.6	4.1	3.2	8.0
	Max.	6	3.4	336.0	0.0	314.0	560.0	34.6	10.2	39.8	14.2
	Avg.			206.0	0.0	256.5	411.3(4)	*13.8(5)	6.4(5)	16.9(5)	11.6
560	Min.		3.7	33.0	0.0	111.0	190.0	0.0	1.0	1.6	50.0
	Max.	6	4.7	120.0	0.0	222.0	450.0	0.6	4.8	12.3	104.0
	Avg.			74.2	0.0	169.5	287.0(5)	0.4	2.8	5.8	76.2
561	Min.		6.9	0.0	31.0	147.0	112.0	0.0	0.0	0.0	8.8
	Max.	6	7.1	90.0	280.0	1480.0	1100.0	1.3	0.3	3.8	14.0
	Avg.			21.3	78.0	411.7	329.4(5)	0.6	0.2	1.4	11.6
562	Min.		6.4	0.0	13.0	147.0	160.0	0.0	0.7	0.0	12.8
	Max.	6	7.0	20.0	30.0	345.0	400.0	1.6	1.1	2.2	32.0
	Avg.			10.2	20.2	206.3	233.8(4)	1.0	0.9	1.0	23.5

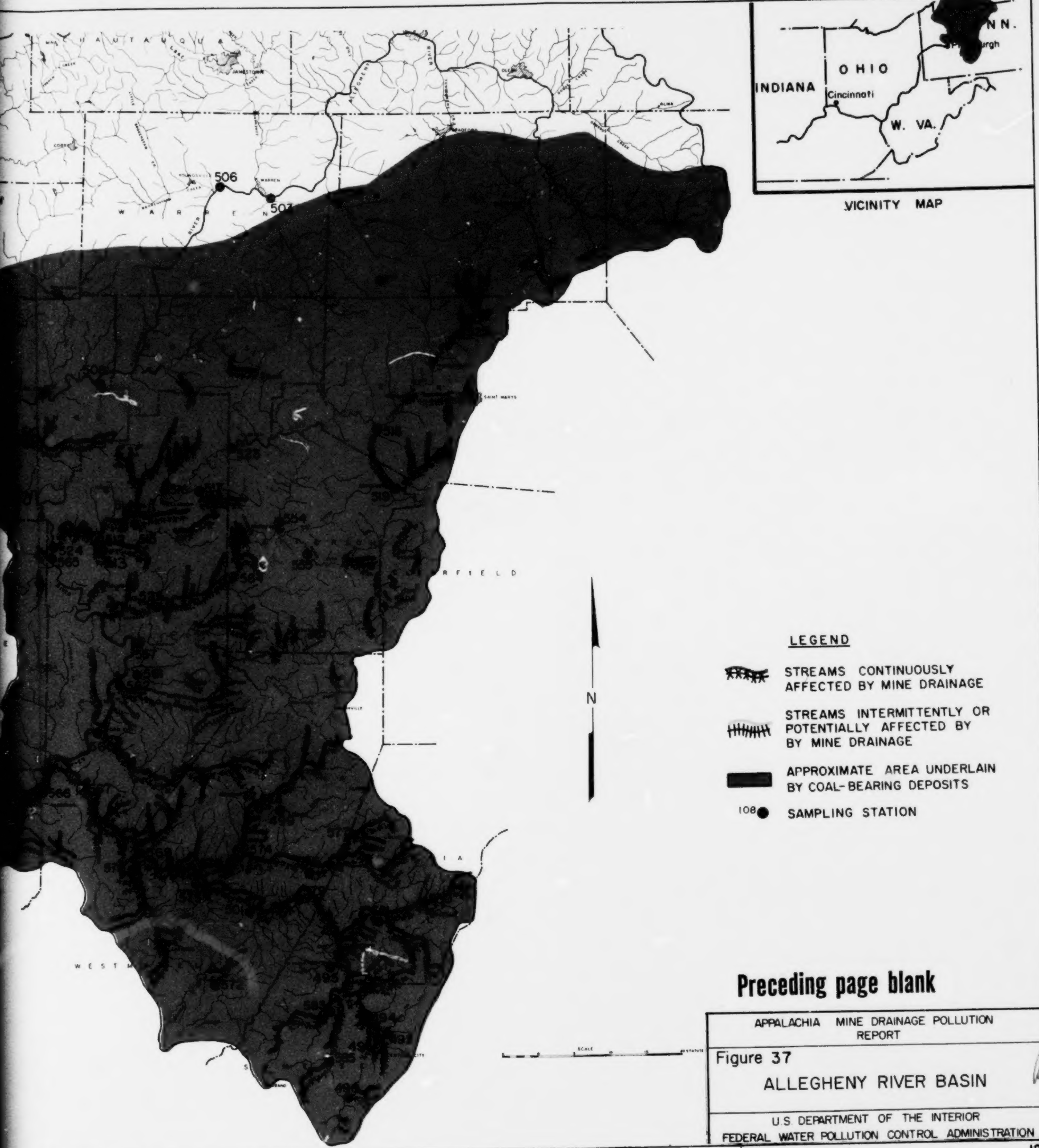
Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Total Manganese (mg/1)	Total Aluminum (mg/1)	Flow (cfs)
565	Min.		6.4	0.0	36.0	74.0	28.0	0.3	0.2	0.7	1392.0
	Max.	6	7.7	13.0	54.0	140.0	175.0	0.7	0.7	3.1	4876.0
	Avg.			7.7	45.8	102.0	62.3	0.5	0.5	1.8	2994.3
566	Min.		4.0	2.0	0.0	115.0	95.0	0.2	1.6	0.5	1866.0
	Max.	6	6.8	158.0	23.0	240.0	270.0	1.1	5.2	5.1	12840.0
	Avg.			37.3	9.8	167.5	178.8(4)	0.5(5)	3.1	2.4(5)	7574.8
567	Min.		3.0	159.0	0.0	264.0	425.0	5.5	9.0	12.2	421.0
	Max.	6	3.6	259.0	0.0	454.0	700.0	32.6	76.9	39.8	1136.0
	Avg.			221.7	0.0	343.3	552.5(4)	12.2	23.2	21.0	853.2
569	Min.		3.1	60.0	0.0	80.0	340.0	3.4	1.9	5.6	5.0
	Max.	6	5.0	171.0	2.0	382.0	600.0	21.6	2.6	31.9	29.0
	Avg.			112.8	0.5	274.2	518.0(5)	10.7	2.3	14.3	15.3
570	Min.		3.3	104.0	0.0	125.0	120.0	2.4	4.1	0.0	60.0
	Max.	6	4.7	193.0	0.0	500.0	680.0	18.5	8.2	17.9	296.0
	Avg.			141.8	0.0	348.2	435.0(5)	11.4	5.8	6.2	136.3
572	Min.		6.7	5.0	12.0	21.0	0.0	0.0	0.0	0.0	16.5
	Max.	6	10.1	11.0	39.0	52.0	15.0	1.6	0.2	4.4	37.9
	Avg.			8.7	22.2	35.2(5)	6.5(4)	0.3	0.1	1.7	25.2
573	Min.		2.5	452.0	0.0	239.0	130.0	48.0	3.2	22.2	53.0
	Max.	6	2.9	897.0	0.0	269.0	920.0	158.4	5.5	168.0	330.0
	Avg.			601.5	0.0	248.8	522.5(4)	93.8	4.0	82.8	125.2
574	Min.		3.0	189.0	0.0	222.0	130.0	27.8	1.2	10.8	21.0
	Max.	6	4.3	467.0	0.0	381.0	750.0	40.8	5.7	84.0	86.0
	Avg.			308.7	0.0	284.0	528.0(5)	34.7	3.8	44.5	50.3

Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Total Manganese (mg/1)	Total Aluminum (mg/1)	Flow (cfs)
575	Min.	6	2.9	167.0	0.0	234.0	440.0	4.3	8.8	6.4	460.0
	Max.		3.3	274.0	0.0	320.0	475.0	12.5	22.8	26.3	901.0
	Avg.			207.3	0.0	274.5	456.3(4)*	7.8	15.1	13.9	724.8
576	Min.	6	2.7	614.0	0.0	247.0	1450.0	91.0	3.5	70.0	56.0
	Max.		2.8	1592.0	0.0	410.0	2500.0	312.0	6.5	176.4	105.0
	Avg.			999.8	0.0	311.2	1845.8	215.2	4.6	124.8(5)	73.8
577	Min.	6	2.7	711.0	0.0	110.0	1150.0	163.2	2.9	14.0	21.0
	Max.		2.9	1572.0	0.0	342.0	2500.0	374.4	7.0	179.2	47.5
	Avg.			1010.5	0.0	272.0(5)	1720.0(5)	257.1	5.2	96.8	35.4
578	Min.	6	3.0	95.0	0.0	202.0	50.0	1.4	2.6	7.8	8.0
	Max.		5.2	261.0	2.0	414.0	450.0	11.0	5.9	35.3	42.0
	Avg.			169.5	0.7	283.0	315.0(5)	5.5(5)	4.0	19.1(5)	28.1
579	Min.	6	5.4	79.0	3.0	140.0	400.0	7.7	22.0	0.1	229.0
	Max.		6.8	160.0	76.0	370.0	840.0	67.2	41.7	47.6	512.0
	Avg.			106.5	19.3	257.8	580.0(5)	22.0	29.8(5)	12.9	373.3
580	Min.	6	6.7	0.0	20.0	80.0	20.0	0.0	0.2	0.0	0.5
	Max.		8.3	15.0	102.0	130.0	88.0	1.5	0.6	2.5	3.8
	Avg.			4.0	71.5	95.2	49.6(5)	0.5	0.3	0.6	2.4
581	Min.	6	3.0	184.0	0.0	212.0	475.0	10.6	3.7	0.0	0.0
	Max.		4.2	330.0	0.0	452.0	805.0	26.4	5.7	41.4	80.0
	Avg.			244.2	0.0	336.3	598.0(5)	17.8	4.4	17.7	40.9
583	Min.	6	5.1	0.0	2.0	95.0	62.0	0.0	0.0	0.2	0.1
	Max.		6.9	43.0	38.0	200.0	215.0	0.5	2.3	3.6	12.0
	Avg.			17.0	20.3	145.8	147.4(5)	0.2	1.1	1.5	3.9
584	Min.	6	6.0	0.0	10.0	113.0	75.0	0.6	0.5	0.9	28.0
	Max.		7.2	16.0	35.0	140.0	120.0	3.6	1.4	6.4	82.5
	Avg.			6.7	26.0	128.7	97.5	1.7	0.9	2.4	59.9

Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Total Manganese (mg/l)	Total Aluminum (mg/l)	Flow (cfs)
585	Min.		6.6	5.0	12.0	187.0	155.0	0.0	0.2	0.0	14.5
	Max.	6	7.0	16.0	28.0	237.0	235.0	0.5	0.7	1.9	30.0
	Avg.			11.5	19.7	210.0	193.8(5)	0.2	0.5	0.6	23.8

* ( ) Indicates the number of samples used in averages when other than the maximum.


CHAUTAUQUA
LAKE
JAMESTOWN
ERIE
WATERFORD
FRENCH
CORRY
CAMBRIDGE SPRINGS
CRAWFORD
MEADVILLE
WARREN
YOUNGSVILLE
BROKENSTRAW
RIVER
WARREN
506
507
ALLEGHENY
RIVER
OLEAN
BRADFORD
ALMA
SAINT MARYS
MERCER
SHARON
509
524
565
BUTLER
557
561
566
586
572
WESTMORELAND
CLEARFIELD
N
SCALE
STATUTE


C H A U T A U Q U A
JAMESTOWN
W A R R E N
WARREN
506
507
SAINT MARYS
R F I E L D
WEST M
OHIO
INDIANA
Cincinnati
W. VA.
PENN.
Pittsburgh
VICINITY MAP
N
SCALE
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
108● SAMPLING STATION

Preceding page blank

APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 37

ALLEGHENY RIVER BASIN

B

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

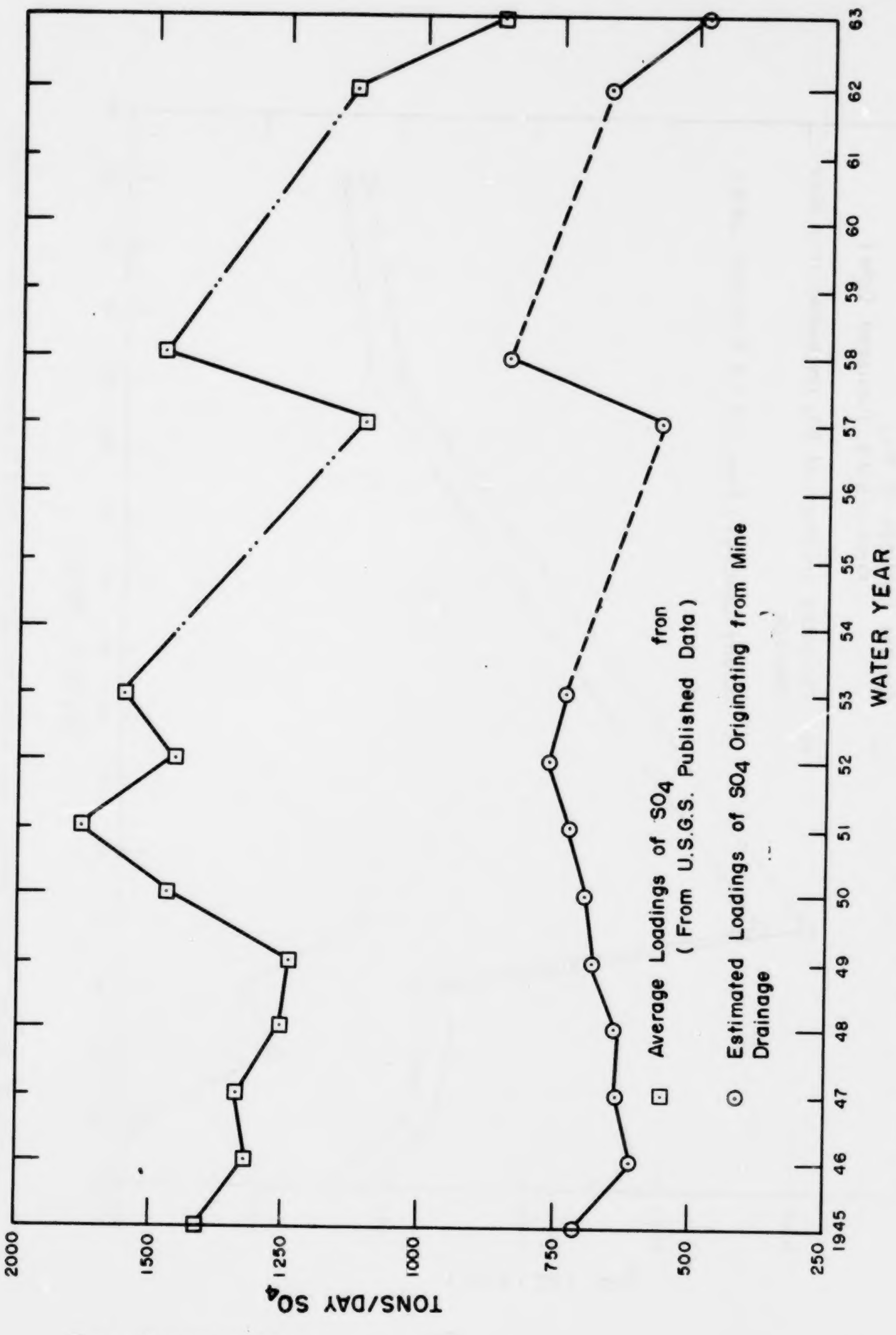


Figure 38. Average loads of total sulfate and sulfate considered to originate from coal mine drainage carried by the Allegheny River at Kittanning, Pennsylvania.

Preceding page blank

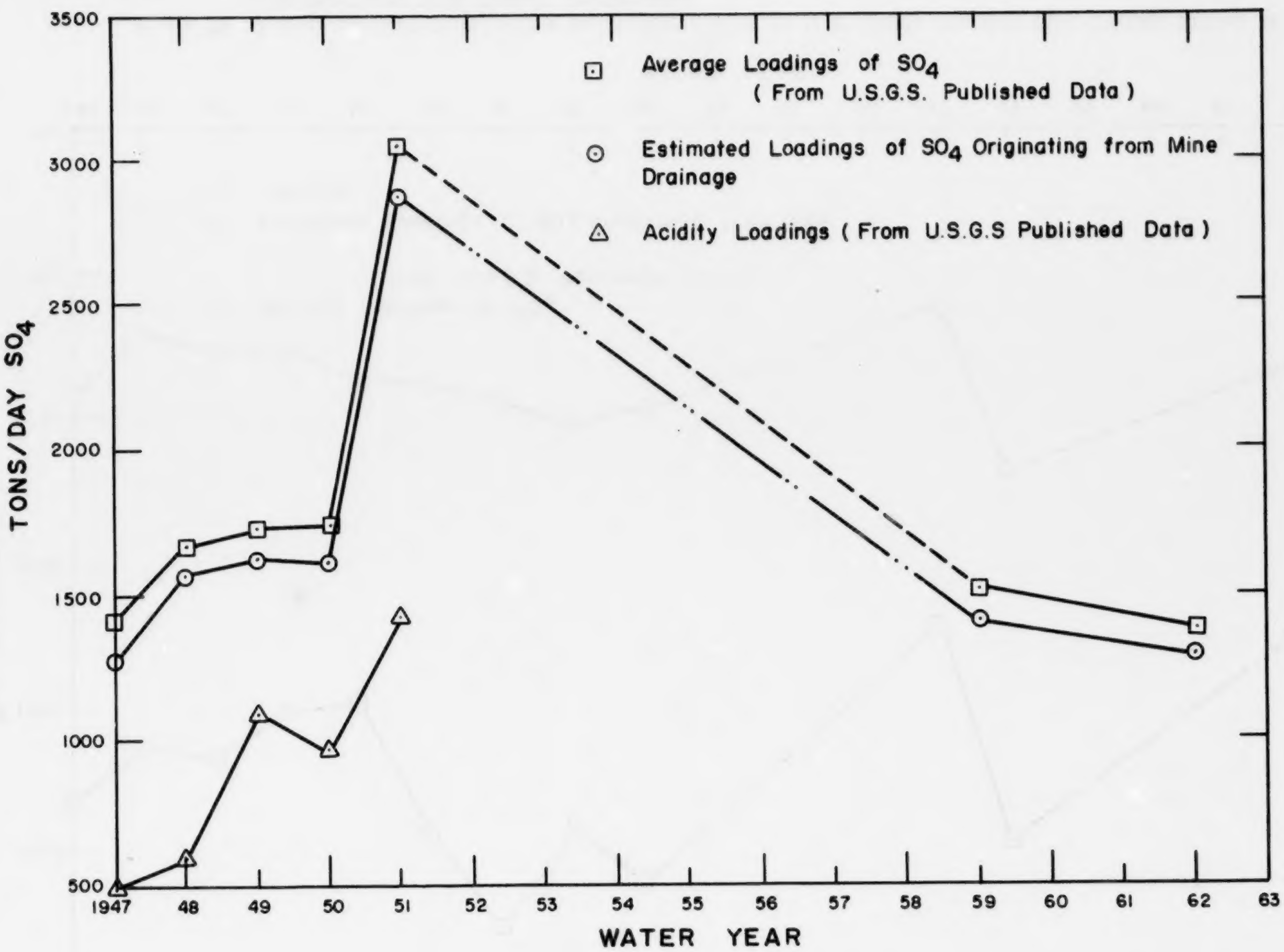


Figure 39. Average loads of acidity, total sulfate and sulfate considered to originate from coal mine drainage carried by the Kiskiminetas River at Vandergrift, Pennsylvania.

Monongahela River Basin

Description

The Monongahela River basin includes about 7,380 square miles in northern West Virginia, southwestern Pennsylvania, and northwestern Maryland all of which is within the Appalachian Region (Fig 40). West Virginia contains the largest share of the basin, 4,150 square miles. Pennsylvania and Maryland contain approximately 2,730 and 500 square miles, respectively. The basin is bounded on the west by main stem Ohio River drainage, on the south by the Little Kanawha and Kanawha River basins, on the east by the Potomac River basin, and on the north by the Allegheny River basin. It includes all or part of 11 counties in West Virginia, six counties in Pennsylvania, and one county in Maryland.

The Monongahela River is formed by the confluence of the West Fork and Tygart Valley Rivers at Fairmont, W. Va. The river flows 129 miles in a northernly direction and joins the Allegheny at Pittsburgh to form the Ohio River. Major tributaries are the Youghiogheny, Cheat, West Fork, and Tygart Valley Rivers. The Monongahela basin is maintained for navigation by lock and dam installations through its entire length.

This area of the Monongahela River basin represents a mature plateau of fine texture with moderate to strong relief. Erosion has reduced almost all the land area to slope, the terrain is rugged, and the valleys are deep and narrow. Flat areas are limited to narrow flood plains and some terraces and flat-topped hills. The elevations of the basin range from a high of about 4,600 feet in the headwaters of the Cheat River to about 700 feet at Pittsburgh, Pennsylvania, giving a maximum relief of nearly 4,000 feet.

Bituminous coal reserves are present in 17 of the 18 counties that are wholly or partly in the basin. These reserves have been estimated to be about 23 billion tons. Coal has been mined in this area for some 200 years. Some mining has been done in all 17 counties, and in 1965 production from approximately 750 mines was about 65 million tons. Marion, Monongalia, Harrison, Preston, and Barbour in West Virginia, and Green, Washington, Westmoreland, Fayette, Somerset, and Allegheny in Pennsylvania were the principal producing counties.

Mine Drainage Sources and Their Effect on Stream Quality

Records of State and Federal agencies indicate that more than 3,000 coal mines have been opened in the Monongahela basin. Each of these mines is a possible source of drainage pollution and many of these mines discharge drainage from a number of points.

Work initiated as a result of the Monongahela River Conference of August 7, 1963, (U.S. Department of Health, Education, and Welfare, 1963) has led to the location and description of over 7,000 underground and surface mines, refuse piles, and coal preparation plants that are present or potential pollution sources. Of these sites that were located and described, about 3,000 were found to be discharging pollutants at the time they were visited. The distribution of pollution sources by type and the relative pollution contributions of the various types are shown in Table 1-A. The table shows that inactive underground mines are the largest single pollution source, contributing about 41 percent of the acidity measured. Active underground mines were contributing about 29 percent of acidity, bringing the total contribution of underground mines to 70 percent. Detailed reports, in which each of the mine drainage sources that were inventoried are listed and pollution abatement measures and costs are discussed, are being prepared for 30 sub-areas of the Monongahela River basin. These reports will be submitted to the Technical Committee of the Monongahela River Enforcement Conference and subsequently to the conferees, which include the States of Maryland, Pennsylvania, and West Virginia, the Ohio River Valley Water Sanitation Commission, and the Federal Government.

Mine drainage pollutants discharged from surface and underground sources cause continuous significant pollution of 1,382 miles of streams and intermittent significant pollution of 289 miles of streams (Table 8).

The significance of these numbers is not obvious in terms of the water uses preempted by this pollution. Further examination shows that, for example, within the Lower West Fork watershed, a highly mined area, 100 percent of the West Fork and 75 percent of the streams directly tributary to the West Fork are severely degraded. The percentage of polluted stream miles as compared to the total stream miles decreases with decreasing tributary size. Only 24 percent of the smallest tributaries are polluted, but these streams are small and remote and do not receive the use accorded the larger streams. Overall, including streams of all sizes, 56 percent of the miles of streams in the West Fork watershed below Clarksburg are severly polluted. In

Table 8 - Lengths of Streams Polluted by Mine Drainage, Monongahela River Basin

	Drainage Area (square miles)	Continuous (miles)	Intermittent (miles)	Total
Monongahela River	8,038	129		129
Minor Tributaries		341	33	374
Youghiogheny River	1,768		105	105
Tributaries		129	27	156
Cheat River	1,424	19	17	36
Tributaries		134	9	143
West Fork River	882	30	18	48
Tributaries		371	20	391
Tygart Valley River	1,369	48		48
Tributaries		181	60	241
		1,382 +	289 =	1,671

contrast, 43 percent of the Buckhannon River is degraded below desirable quality and only 14 percent of the stream miles in this watershed are degraded to this level. The conclusion can easily be reached from glancing at Figure 40 or from statistical exercises such as given above that relatively large amounts of the available miles of the larger more usable streams are badly degraded and that the largest percentage of unaffected or slightly affected stream miles are comprised by the smaller tributaries.

Based on sulfate loadings in the Monongahela River at Charleroi (Figure 41) and in the Youghiogheny River at Sutersville (Figure 42), it is estimated that about 3,000 tons/day of acidity were formed in the Monongahela basin during the period 1945-1958. About 2,500 tons/day were formed in the Monongahela basin above Charlerio and 500 tons/day were formed in the Youghiogheny basin. It is estimated that 1,200 tons/day of unneutralized acidity enters streams in the basin at the present time. Figure 41 shows that the Monongahela River carried an average of 600 tons/day of acidity at Charlerio during 1945-1953.

A comprehensive water quality survey of the streams in the Monongahela River basin was conducted during 1965-1966. Those streams that have been found to carry more than 5 tons/day net acidity are shown in Table 9.

Although the West Fork River receives small amounts of mine drainage from minor headwater tributaries in Lewis County, West Virginia, the first mine drainage of serious proportions is received in Harrison County where virtually every tributary is polluted. Elk Creek alone discharges an average of 6 tons/day net acidity (Sta. 132). Just below Clarksburg, West Virginia, the West Fort River (Sta. 122) discharged

Table 9 - Acidity Loads in Monongahela Basin Streams Carrying More Than 5 tons/day Net Acidity

Sampling Station Number	Stream	Location	Average Net Acidity Load - tons/day
117	West Fork River	Above Fairmont, W.Va.	156
120	Simpson Creek	Below Bridgeport, W.Va.	29
122	West Fork River	Below Clarksburg, W.Va.	6.5
132	Elk Creek	Near Clarksburg, W. Va.	6
104	Tygart Valley River	Colfax, W. Va.	38
106	Tygart Valley River	Below Tygart Reservoir	14
105	Tygart Valley River	Below Grafton, W.Va.	20
90	Big Sandy Creek	Rockville, W. Va.	5
94	Cheat River	Albright, W. Va.	25
401	Cheat River	Point Marion, Pa.	204
432	Redstone Creek	Below Uniontown, Pa.	5.7
433	Monongahela River	Brownsville, Pa.	470
434	Monongahela River	Millsboro, Pa.	448
425	Monongahela River	Pittsburgh, Pa.	462
429	Monongahela River	Wilson, Pa.	495
441	Monongahela River	Masontown, Pa.	360
127	Monongahela River	Star City, W. Va.	235
128	Deckers Creek	Morgantown, W. Va.	5.3
129	Monongahela River	Hildebrand Lock and Dam	183
130	Monongahela River	Lock 15, Fairmont, W.Va.	118
402	Monongahela River	Point Marion, Pa.	220
403	Youghiogheny River	Above Mckeesport, Allegheny County, Pa.	144
405	Sewickley Creek	Near Mouth, Westmoreland County, Pa.	20
410	Youghiogheny River	Below Connellsville, Pa.	28
415	Youghiogheny River	At Ohiopyle, Pa.	35
417	Casselman River	Below confluence of Whites Creek	30
419	Casselman River	At Markleton, Pa.	25
421	Casselman River	Below Piney Creek	5
424	Youghiogheny River	Below Youghiogheny Reservoir	7
447	Youghiogheny River	Above Jacobs, Pa.	26
3	Youghiogheny River	Below Little Youghiogheny River, Garrett County, Maryland	10
95	Cheat River	Rowlesburg, W.Va.	15

an average of 6.5 tons/day of acidity and had minimum pH of 4.3. The West Fork becomes grossly polluted by mine drainage in its lower section between Clarksburg and Fairmont, W. Va. Many poor quality tributaries enter the stream in this reach. Simpson Creek (Sta. 120) contributed an average net acidity load of 29 tons/day. Other tributaries with significant acidity loads are Ten Mile Creek and Little Ten Mile Creek. At its mouth (Sta. 117) the West Fork River carried an average acidity load of 156 tons/day, had a minimum pH of 3.0 and an average sulfate concentration of over 1000 mg/l.

The Tygart Valley River basin has much less coal mining and fewer mine drainage pollution sources than the West Fork River basin and therefore, contributes less acid to the Monongahela River. The Tygart Valley River is of good quality until it receives mine drainage from Roaring Creek in Randolph County. Further downstream in Barbour County, the Middle Fork River and Buckhannon River contribute acidity. Several small tributaries to the Buckhannon River in Barbour County carry relatively large amounts of acidity. During the survey, the Tygart Valley River just below Philippi (Sta. 108) had a minimum pH of 4.8. At a sampling station just below the Tygart Reservoir in Taylor County (Sta. 106) the average net acidity discharge was 14 tons/day, and the alkalinity was below desirable levels at all times. Further downstream, Threefork Creek contributed more acid, and the Tygart just below Grafton (Sta. 105) carried 30 tons/day of net acidity. At Colfax, near the mouth of the Tygart (Sta. 104), the average net acidity load was 36 tons/day and the minimum pH was 4.7.

The Cheat River receives its first mine drainage pollution from the Blackwater River and its headwater tributaries in Tucker County, West Va. Just below Parsons (Sta. 96) the Cheat River had a minimum pH of 6.7. At Rowlesburg (Sta. 95) the Cheat had a minimum pH of 6.8. At Albright (Sta. 94) the average net acidity load was 25 tons/day and the minimum pH was 4.8. This decrease in quality is attributed to many small acid tributaries in central Randolph County. Minor acid streams such as Big Sandy Creek and Bull Run in the northern part of the County contribute additional acid to Cheat River. Big Sandy Creek at Rockville, W. Va., (Sta. 90) discharged 5 tons/day net acidity. The Cheat River at Point Marion, Pa., below Lake Lynn Reservoir (Sta. 401) discharged an average acid load of 204 tons/day. The pH ranged from 2.9 to 4.2, and sulfate concentrations were as high as 2500 mg/l. Much additional acid is received by the Cheat from mine discharges in Fayette County, Pennsylvania.

The main stem Monongahela River at Fairmont (Sta. 130) discharged 118 tons/day net acidity, and the pH was from 3.9 to 6.2. Many minor tributaries such as Buffalo Creek, Paw Paw Creek, Scotts Run, and Beckers Creek contribute acidity to the Monongahela between Fairmont and Morgantown. The Monongahela at Star City (Sta. 127) discharged 235 tons/day acidity and had a minimum pH of 3.4.

Below the mouth of the Cheat River, many tributaries, including Dunkard Creek, Ten Mile Creek, and Redstone Creek discharge acidity to the Monongahela. At Wilson, Pennsylvania (Sta. 429), the Monongahela River carried an average load of 495 tons/day net acidity and had high concentrations of sulfate, iron, manganese, and hardness. The pH ranged between 5.2 and 6.1.

The Youghiogheny River, the largest tributary to the Monongahela in Pennsylvania, first receives some mine drainage pollution from a few small headwaters tributaries such as Snowy Creek in Garrett County, Maryland, The Youghiogheny River just below the Little Youghiogheny River discharged 10 tons/day of acidity. Neutralization of some of the acidity in the Youghiogheny River decreased the load downstream, and near Friendsville, Maryland, the Youghiogheny carried only 3 tons/day acidity (Sta. 002). Just below the Youghiogheny Reservoir (Sta. 424) the acidity load had slightly increased to an average of 7 tons/day.

The Casselman River, tributary to the Youghiogheny River, is intermittently polluted by mine drainage in its headwaters in Garrett County, Maryland. Several small tributaries downstream from Salisburg, Pennsylvania, discharge acidity to the River, and above Meyersdale, Pennsylvania (Sta. 421), the acid load carried was 5 tons/day. Between Meyersdale, Pennsylvania and Markleton, Pennsylvania (Sta. 419), other minor acid streams increased the net acidity load to 25 tons/day. The Casselman River near its mouth (Sta. 417) had a total average net acidity load of 30 tons/day. The minimum pH at this point was 4.5. At Ohiopyle, Somerset County (Sta. 415) the Youghiogheny River carried an average net acidity load of 35 tons/day. This increase in acid load over that measured at the Youghiogheny Reservoir was received primarily from the Casselman River.

Minor tributaries to the Youghiogheny in Fayette, Westmoreland, and Allegheny Counties contributed some acid and produced intermittent stream pollution. Sewickley Creek near its mouth in Westmoreland County (Sta. 405) discharged an average of 20 tons/day net acidity, and had a minimum pH of 4.9. The Youghiogheny at its mouth at Mckeesport, Pennsylvania (Sta. 403) carried an average net acidity load of 90 tons/day. The minimum pH was 4.8. At. Pittsburgh, Pennsylvania (Sta. 425), the Monongahela River discharged an average net acidity load of 462 tons/day to the Ohio River and had a minimum pH of 5.0. This analysis is based on 9 samples taken during 1966.

Table 10- Water quality data, Monongahela River basin

Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Total Manganese (mg/1)	Total Aluminum (mg/1)	Flow (cfs)
90	Min.		6.3(9)	1.0	0.0	28.0	19.0	0.1	0.2		4.2
	Max.	8	8.2	32.0	18.0	80.0	34.0	0.5	0.5		992.0
	Avg.			16.3	8.8	57.9	26.6	0.2	0.3(5)*	0.3(1)	196.6
94	Min.		3.4	15.0	0.0	32.0	22.0	0.3	0.0		26.0
	Max.	12	6.5	86.0	3.0	96.0	85.0	2.8	0.3		1600.0
	Avg.			34.3	0.9	71.8	53.8	1.1	0.1(9)		438.2
95	Min.		6.8	5.0	5.0	26.0	7.0	0.1	0.0		146.0
	Max.	6	7.6	30.0	11.0	69.0	16.0	0.6	0.3		1762.0
	Avg.			16.7	7.3	45.7	10.3(3)	0.2	0.1(4)		870.7
96	Min.		6.7	0.0	4.0	26.0	3.0	0.0	0.0		48.0
	Max.	12	9.0	47.0	26.0	74.0	40.0	1.0	0.3		1031.0
	Avg.			11.9	13.3	55.1	25.0	0.3	0.1(7)	0.4(1)	356.7
104	Min.		4.7	15.0	0.0	34.0	23.0	0.0	0.0		110.0
	Max.	10	7.5	41.0	8.0	70.0	42.0	1.1	0.6		2640.0
	Avg.			27.5	1.7	54.7	32.7	0.3	0.3(9)		653.7
105		1	7.3	30.0	5.0	52.0	16.0	0.2	0.3		445.0
106	Min.		6.8	27.0	1.0	44.0	16.0	0.2	0.3		120.0
	Max.	2	7.2	33.0	2.0	60.0	17.0	0.4	0.6		250.0
	Avg.			30.0	1.5	52.0	16.5	0.3	0.5		185.0
108	Min.		4.8	12.0	0.0	42.0	19.0	0.0	0.0		16.7
	Max.	12	7.4	39.0	45.0	112.0	92.0	1.3	0.8		2056.0
	Avg.			23.1	7.2	76.0	57.0	0.4	0.4(9)		450.2

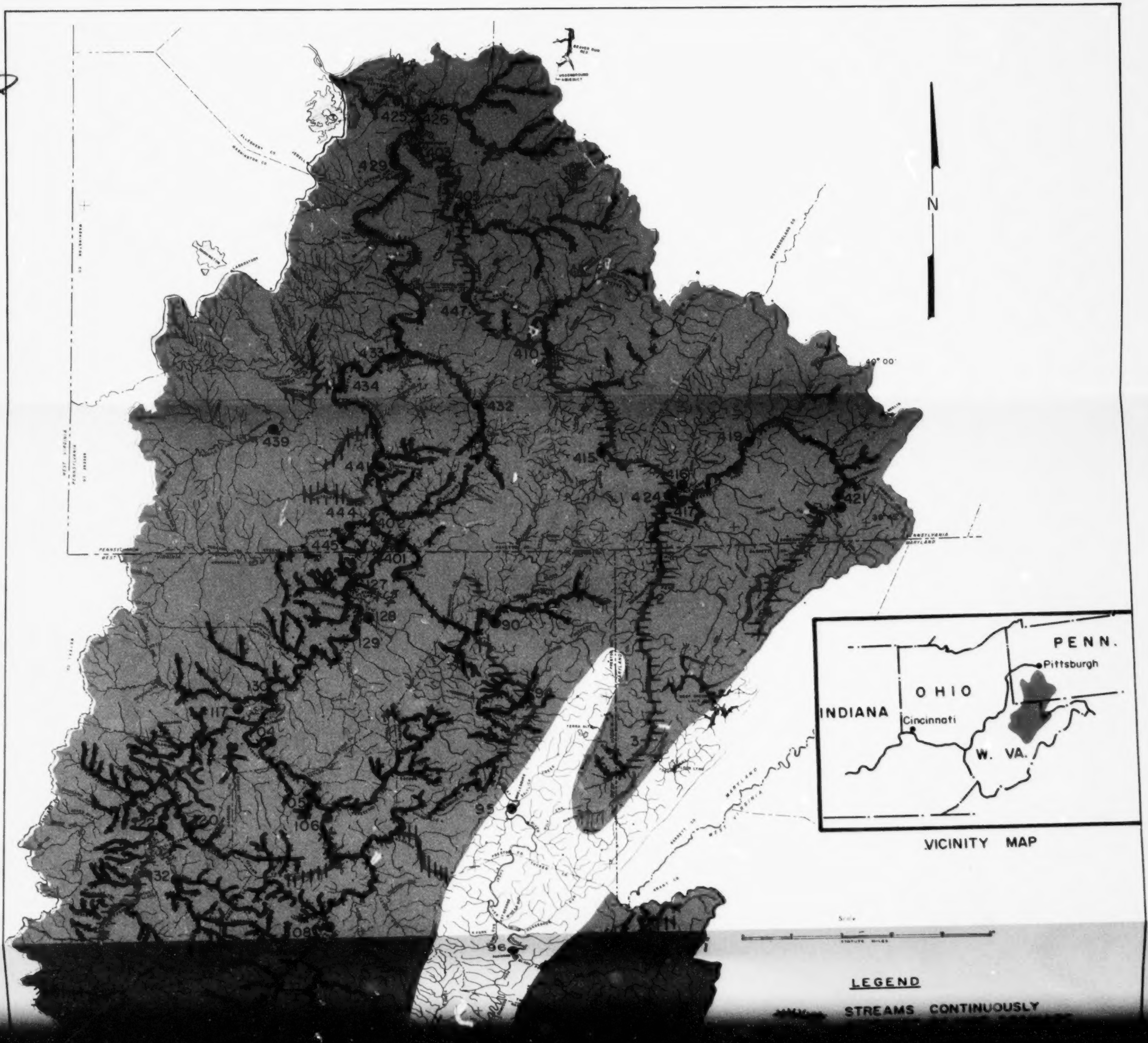
Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Total Manganese (mg/l)	Total Aluminum (mg/l)	Flow (cfs)
117	Min.		2.9	17.0	0.0	400.0	460.0	3.3	0.0		20.0
	Max.	12	3.5	362.0	0.0	1040.0	1400.0	18.2	7.6		2400.0
	Avg.			216.6	0.0	782.5	1046.9	8.5	4.4		353.7
120	Min.		2.8	300.0	0.0	708.0	750.0	13.2	0.2		5.3
	Max.	9	3.1	418.0	0.0	1100.0	2750.0	41.6	8.6		92.0
	Avg.			366.7	0.0	928.2	1364.4	23.5	6.5		27.6
122	Min.		4.3	4.0	0.0	39.0	200.0	0.7	1.6		2.5
	Max.	13	6.3	75.0	50.0	960.0	1300.0	7.8	5.1		273.0
	Avg.			38.2	12.8	630.8	686.2	2.8	3.0(9)		63.5
127	Min.		3.4	17.0	0.0	78.0	80.0	1.7	0.4		345.0
	Max.	7	6.7	128.0	9.0	1104.0	900.0	10.4	2.2		27500.0
	Avg.			70.9	1.9	367.4	371.3	3.3	1.4(4)		5250.6
128	Min.		3.1	9.0	0.0	130.0	90.0	2.8	0.6		0.1
	Max.	9	6.8	314.0	30.0	780.0	1225.0	10.3	6.8		348.0
	Avg.			156.2	4.0	426.9	534.1	6.8	2.6(6)	20.3(1)	90.3
129	Min.		3.3	14.0	0.0	100.0	86.0	0.5	0.5		205.0
	Max.	12	6.7	115.0	9.0	360.0	1000.0	3.8	2.5		26000.0
	Avg.			74.7	0.8	230.2	353.0	1.5	1.5(9)		3068.3
130	Min.		3.9	12.0	0.0	112.0	60.0	0.4	0.4		204.0
	Max.	12	6.2	116.0	8.0	326.0	450.0	5.0	2.4		18200.0
	Avg.			55.3	1.5	197.6	198.2	1.5	1.3(9)		2471.4
132	Min.		3.0	152.0	0.0	780.0	660.0	5.0	6.1		6.5
	Max.	3	3.2	260.0	0.0	1120.0	1500.0	15.4	8.1		18.5
	Avg.			201.7	0.0	903.3	1011.7	9.5	6.9		11.4

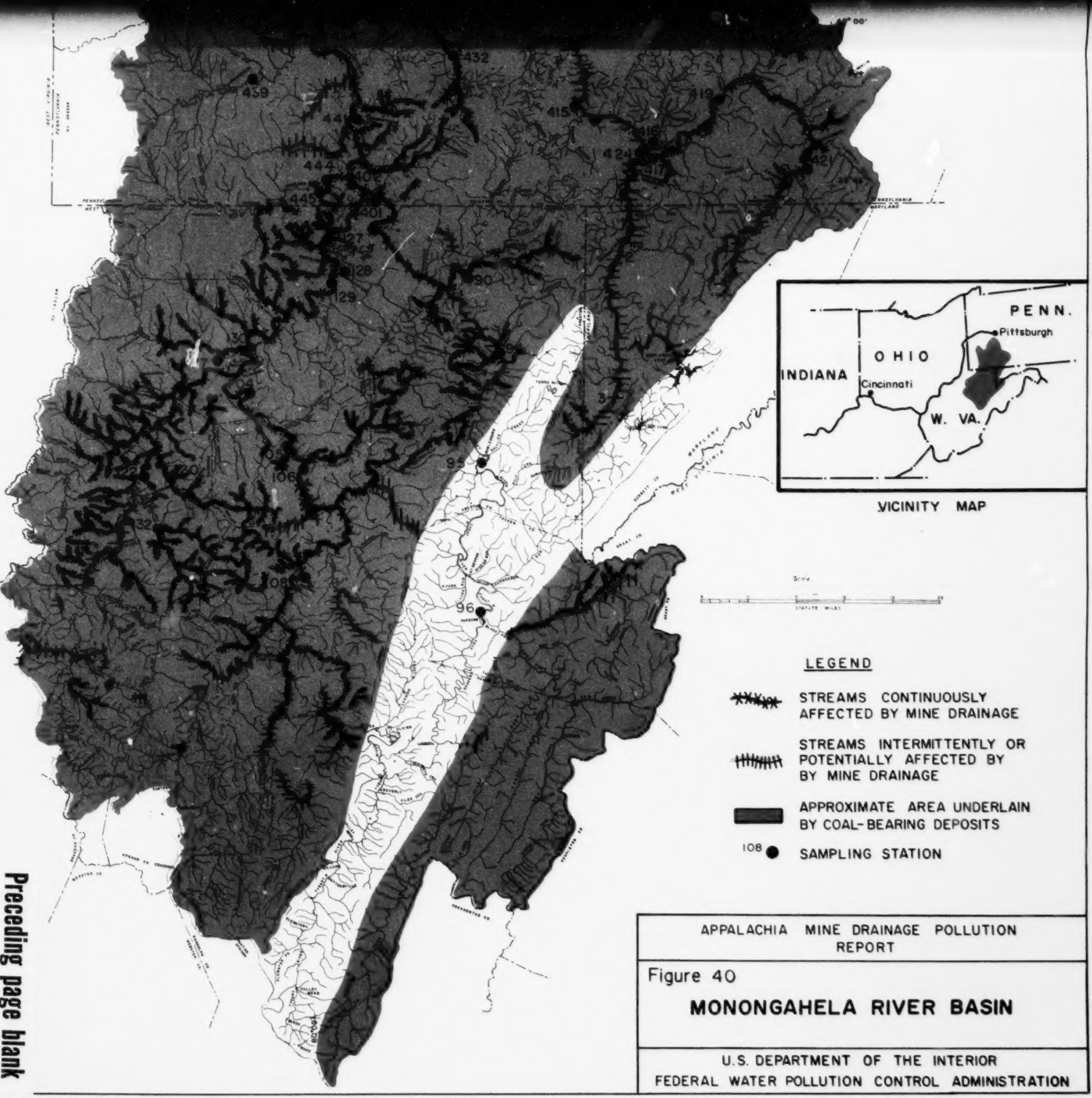
Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Total Manganese (mg/l)	Total Aluminum (mg/l)	Flow (cfs)
401	Min.		2.9	64.0	0.0	46.0	56.0	1.3	0.3	4.5	53.0
	Max.	10	4.2	281.0	0.0	371.0	2500.0	16.4	2.3	10.3	4000.0
	Avg.			133.7	0.0	139.0	430.7	6.6	1.0(6)	7.4(2)	920.6
402	Min.		3.2	13.0	0.0	84.0	100.0	1.0	0.4		410.0
	Max.	13	4.5	179.0	1.0	500.0	1250.0	3.7	3.3		2800.0
	Avg.			121.2	0.2	336.6	505.8	2.3	1.9(10)		990.0
403	Min.		4.8	10.0	0.0	100.0	72.0	1.4	0.3		720.0
	Max.	10	6.3	52.0	8.0	130.0	190.0	6.0	1.0		4644.0
	Avg.			34.2	4.3	143.6(8)	143.4(9)	3.1(9)	0.6(6)		1860.7
405	Min.		4.9	166.0	3.0	630.0	795.0	42.1	3.4		35.4
	Max.	2	5.0	245.0	9.0	770.0	1275.0	49.4	4.0		42.1
	Avg.			205.5	6.0	700.0	1035.0	45.8	3.7		38.8
410	Min.		5.5	7.0	6.0	62.0	20.0	0.6	0.0		375.0
	Max.	10	6.8	36.0	11.0	88.0	74.0	3.9	1.4		6200.0
	Avg.			22.9	8.6	76.9(9)	43.7	1.4	0.5		1718.0
415	Min.		4.7	5.0	1.0	44.0	15.0	0.0	0.0		560.0
	Max.	13	7.8	37.0	15.0	80.0	50.0	1.7	0.5		2420.0
	Avg.			23.1	7.5	59.6	28.7	0.4	0.3		968.5
416	Min.		6.4	5.0	3.0	32.0	4.0	0.0	0.0		14.5
	Max.	6	7.3	26.0	21.0	56.0	9.0	1.0	0.3		460.0
	Avg.			14.0	13.5	45.0	6.7	0.4	0.1		199.0
417	Min.		4.5	12.0	0.0	64.0	61.0	0.1	0.3		36.5
	Max.	10	6.0	97.0	35.0	264.0	210.0	3.8	2.7		1560.0
	Avg.			46.0	5.3	152.3	131.0	0.9	1.2		420.7

Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Total Manganese (mg/l)	Total Aluminum (mg/l)	Flow (cfs)
419	Min.		3.6	10.0	0.0	76.0	51.0	0.0	0.0		37.8
	Max.	9	6.2	120.0	4.0	318.0	470.0	2.2	2.5		1245.0
	Avg.			70.9	0.6	197.1	210.1	0.8	1.5		350.3
421	Min.		4.1	10.0	0.0	62.0	39.0	0.8	0.0		4.8
	Max.	10	6.4	181.0	15.0	284.0	310.0	6.5	3.3		405.0
	Avg.			51.0	5.3	131.7(9)	91.8(9)	2.6(9)	0.8		122.4
424	Min.		5.8	4.0	6.0	24.0	8.0	0.2	0.0		92.5
	Max.	10	7.2	35.0	18.0	46.0	20.0	0.8	0.7		1200.0
	Avg.			18.2	11.0	37.9	11.7	0.5	0.2		501.8
425	Min.		5.0	7.0	0.0	148.0	66.0	0.8	0.4		1775.0
	Max.	9	6.9	64.0	9.0	336.0	470.0	15.8	1.9		29050.0
	Avg.			37.8(8)	6.0(8)	277.7(6)	281.4	3.1	1.3		8953.9
426		1	7.0	45.0	59.0	292.0	195.0	7.0	0.8		50.0
429	Min.		5.2	5.0	0.0	118.0	80.0	0.8	0.4		842.0
	Max.	6	6.1	68.0	7.0	400.0	550.0	8.5	2.9		31000.0
	Avg.			37.3	4.0	311.5(4)	296.2	2.6	1.3		11303.7
432	Min.		6.1	11.0	15.0	210.0	210.0	14.8	1.6		11.6
	Max.	9	6.6	500.0	67.0	1670.0	2900.0	434.6	12.4		560.0
	Avg.			247.3	41.3	1175.8(8)*	1548.3	156.6	7.2		88.9
433	Min.		3.6	6.0	0.0	110.0	66.0	0.5	0.3		1000.0
	Max.	10	6.2	180.0	4.0	460.0	530.0	3.3	14.4		21600.0
	Avg.			94.2	0.7	282.7(9)	320.5	1.6	2.9		5876.0
434	Min.		3.6	5.0	0.0	82.0	65.0	0.2	0.3		1000.0
	Max.	9	6.3	575.0	5.0	400.0	510.0	3.8	4.0		16800.0
	Avg.			138.0	1.0	264.5(8)	293.8	2.1	1.8		4172.2

Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Total Manganese (mg/l)	Total Aluminum (mg/l)	Flow (cfs)
439	Min.		6.9	2.0	5.0	98.0	25.0	0.5	0.1		2.0
	Max.	6	7.2	73.0	154.0	184.0	100.0	3.2	1.4		858.0
	Avg.			25.0	72.3	148.4(5)	50.7	1.1	0.8		257.1
441	Min.		3.1	6.0	0.0	68.0	40.0	2.0	0.4		402.0
	Max.	8	5.6	650.0	50.0	472.0	570.0	16.4	2.5		21300.0
	Avg.			177.7(7)	7.1(7)	224.7(7)	256.0	6.0	1.4(7)		5897.8
444	Min.		3.1	0.0	0.0	94.0	79.0	2.2	0.2		5.9
	Max.	9	7.5	535.0	82.0	820.0	1500.0	22.2	6.0		900.0
	Avg.			170.1	22.7	424.8(8)	646.9	11.2	2.0		147.4
445	Min.		6.4	0.0	26.0	78.0	51.0	0.2	0.0		1.7
	Max.	6	8.1	37.0	130.0	390.0	900.0	2.7	0.1		1800.0
	Avg.			12.2	67.5	220.4(5)	347.2	0.7	0.1		397.9
447	Min.		5.5	5.0	3.0	58.0	32.0	0.1	0.0		600.0
	Max.	9	8.8	34.0	14.0	232.0	77.0	4.2	1.4		6940.0
	Avg.			21.7	7.3	106.0(8)	52.1	1.1	0.4		2027.1

*( ) Indicates the number of samples used in averages when other than the maximum.


N
40° 00'
425
426
403
429
405
447
410
433
434
432
439
415
419
416
424
417
421
441
444
402
445
401
127
128
129
90
130
117
104
105
106
95
96
108
132
PENNSYLVANIA
MARYLAND
WEST VIRGINIA
PENNSYLVANIA
PENN.
Pittsburgh
OHIO
INDIANA
Cincinnati
W. VA.
VICINITY MAP
Scale
STATUTE MILES
LEGEND
STREAMS CONTINUOUSLY


432
439
415
419
416
424
417
421
441
444
440
445
401
127
128
129
90
130
104
95
96
105
106
120
122
132
108
VICINITY MAP
PENN.
Pittsburgh
OHIO
INDIANA
Cincinnati
W. VA.
Scale
STATUTE MILES
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
108 ● SAMPLING STATION

APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 40

MONONGAHELA RIVER BASIN

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

Preceding page blank

B

Preceding page blank

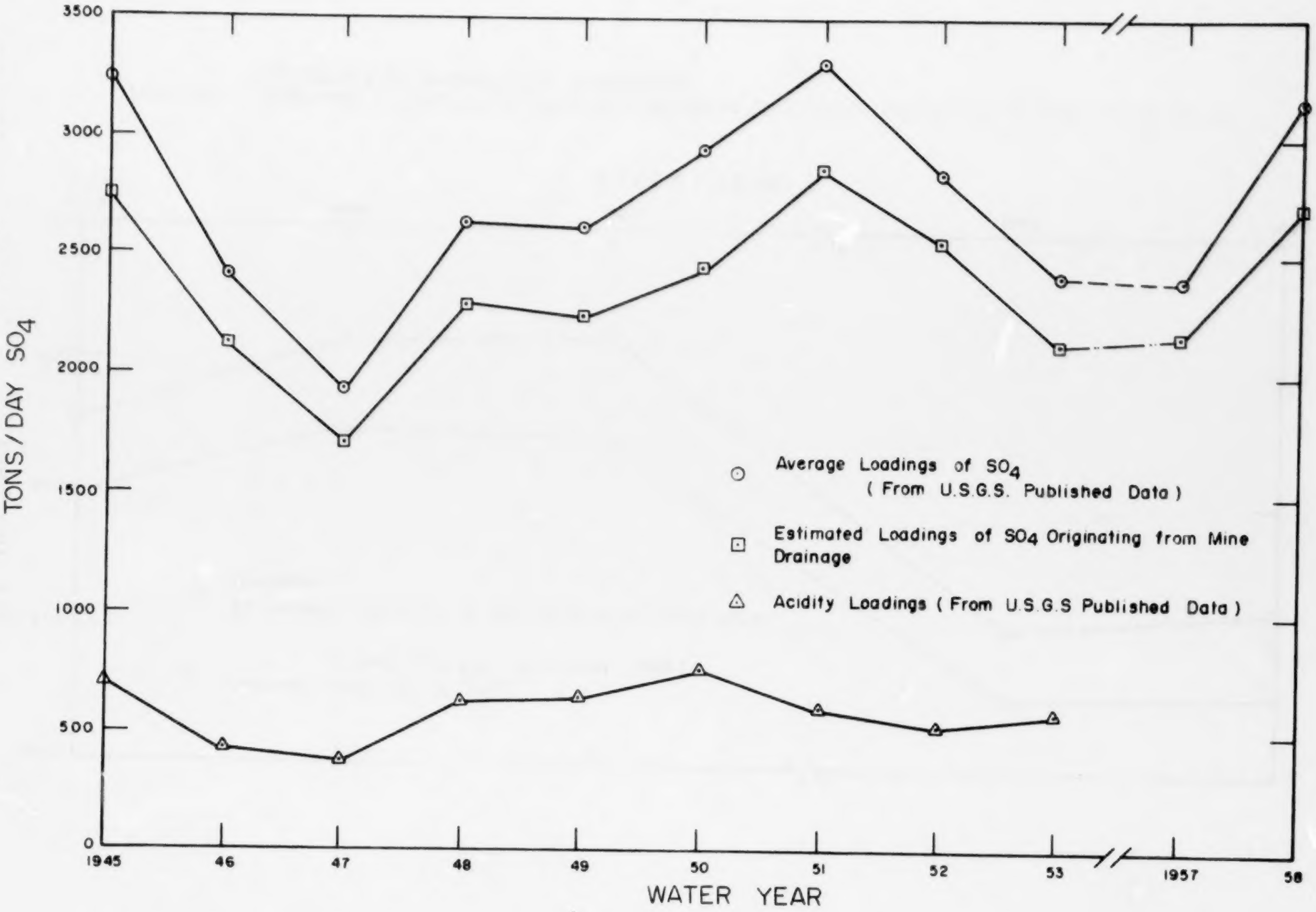


Figure 41. Average loads of acidity, total sulfate and sulfate considered to originate from coal mine drainage carried by the Monongahela River at Charleroi, Pennsylvania.

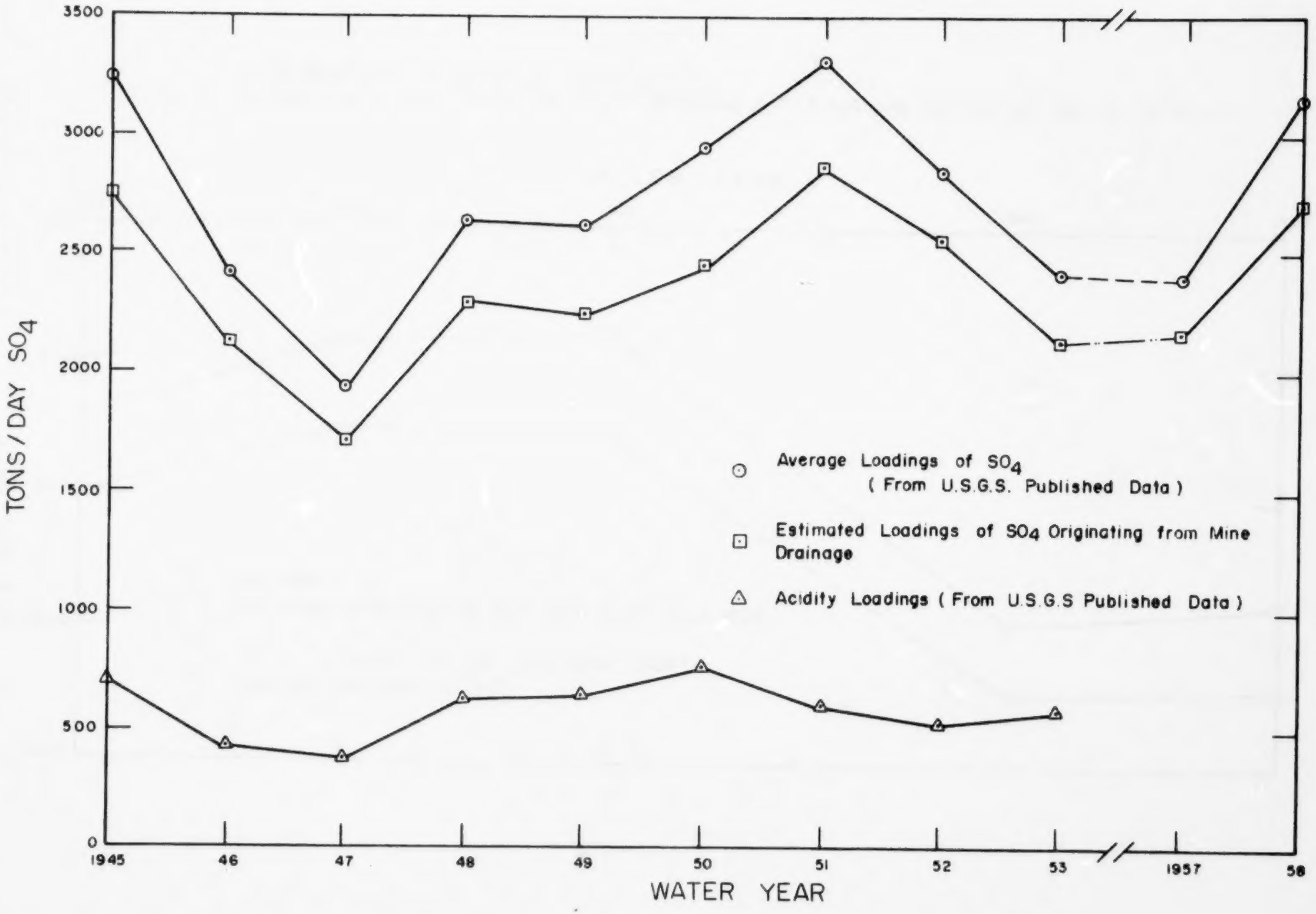


Figure 41. Average loads of acidity, total sulfate and sulfate considered to originate from coal mine drainage carried by the Monongahela River at Charleroi, Pennsylvania.

Preceding page blank

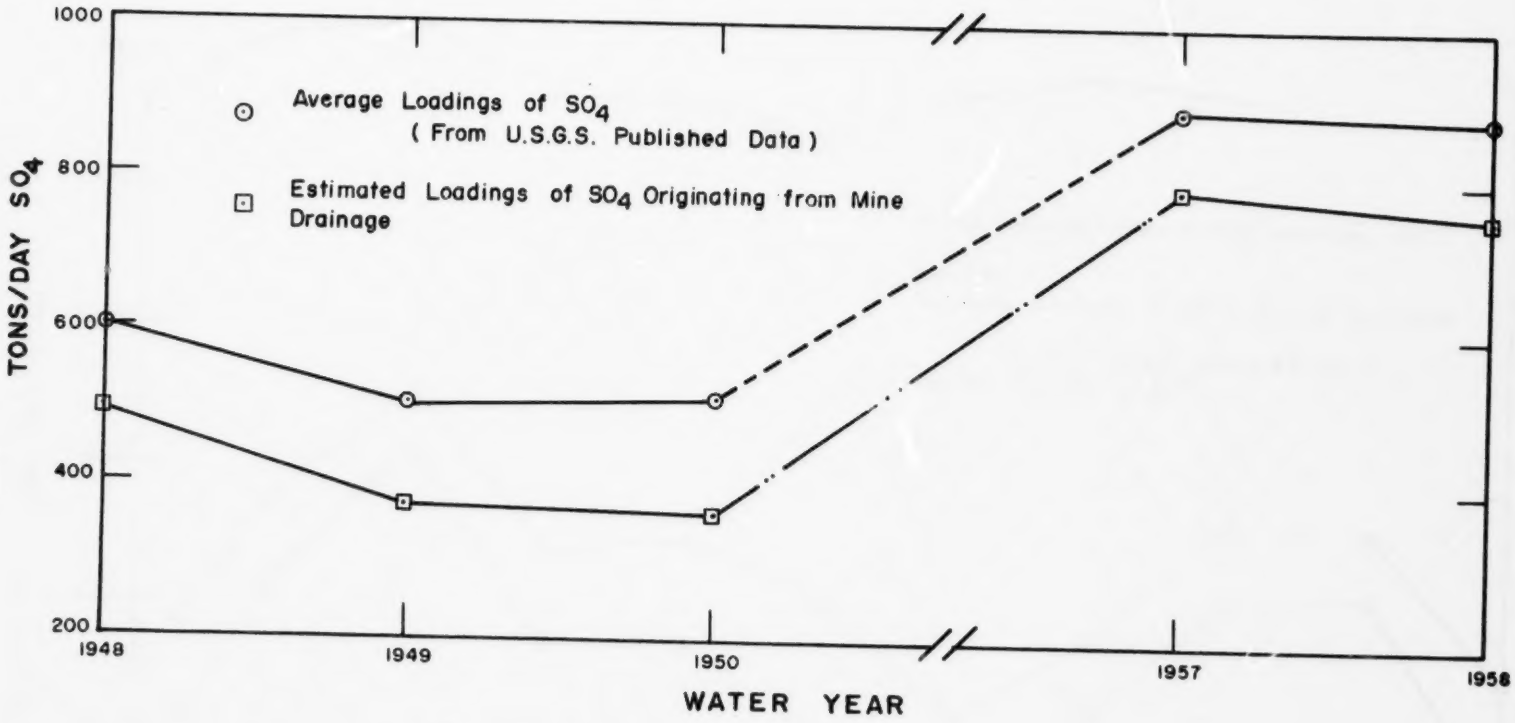


Figure 42. Average loads of total sulfate and sulfate considered to originate from coal mine drainage carried by the Youghiogheny River at Sutersville, Pennsylvania.

Beaver River Basin

Description

The Beaver River basin is located in northeastern Ohio and northwestern Pennsylvania. The Beaver River is formed by the confluence of the Mahoning River and Shenango River near New Castle, Pennsylvania (Fig. 43). It flows in a southerly direction for about 21 miles, then enters the Ohio River at Beaver, Pennsylvania, which is 25 river miles below Pittsburgh, Pennsylvania. The total drainage area of the basin is 3,145 square miles encompassing parts of 13 counties in the two states. Principal tributaries to the Beaver River are the Mahoning and Shenango Rivers and Connoquenessing, Slippery Rock, and Neshannock Creeks.

The Pennsylvania portion of the Beaver River basin, parts of seven counties, is contained within the Appalachian Region. The Ohio portion of the Beaver River basin is not included in the Appalachian Region.

The Beaver River basin is situated in the Appalachian Plateaus physiographic province. The topography of the northern and western portions of the basin has been changed by the continental ice sheets, which rounded the hills and filled most of the bedrock valleys with thick deposits of glacial sediments. The southeastern part of the basin drained by Connoquenessing Creek is unglaciated and is dissected plateau.

Recoverable bituminous coal reserves underlie three-fourths of the Beaver River basin and are estimated to be in excess of three billion tons. Of this total more than two-thirds of the reserve is in the Pennsylvania portion of the basin.

Coal production has been reported in all counties of the basin that contain reserves. Production for 1965 exceeded four million tons. Surface mining accounted for virtually all of the coal produced. (Brant and DeLong, 1960; Ohio Department of Industrial Relations, 1965).

Mine Drainage Sources and Their Effect on Stream Quality

A 1963 survey conducted by the State of Pennsylvania (Pennsylvania Department of Health, 1965) located 935 active and inactive surface and underground mines. Of this total, 590 were surface mines, but 67 percent of the acid discharge measured originated in the 304 abandoned underground mines that were inventoried. Most of the remaining acid discharged originated in active strip mines.

Sulfate loading data obtained during the 1966 stream survey indicate that in the order of 165 tons/day of acidity originates in surface and underground sources in the Slippery Rock Creek watershed. It is estimated that of the 165 tons/day of acidity formed perhaps 50 tons/day enters unneutralized into streams in the watershed.

The Beaver River basin contains about 108 miles of streams polluted by acid mine drainage (Fig. 43). The most seriously affected watershed in the basin is Slippery Rock Creek, which contains about 93 miles of acid polluted streams.

The Slippery Rock Creek drainage basin has had a long history of pollution resulting from mine drainage. Extensive deep mine activities were initiated in the early 1900's. Beginning with the early 1940's the deep mining activity was followed by the onslaught of literally hundreds of strip mines. A 1963 survey of the Slippery Rock Creek watershed showed 935 active and inactive operations. Of this total, 590 of the operations were strip mines.

The large number of mines in the Beaver River basin led to adverse effects on stream quality, but until 1958 the lower reaches of the stream were protected by the alkaline discharges from a limestone plant. When this plant ceased operations in late 1957, the stream became acid from its headwaters to the confluence with the South Branch. On July 12, 1964 an extremely heavy rainstorm fell in the upper, now acid, portion of the creek. This flushed out acidity from swamps, strip mine pits, ponds, and even from the creek itself. As a result of this large amount of acidity moving downstream, two million fish were killed (Pennsylvania Department of Health, 1965).

During the 1966 survey, the North Branch of Slippery Rock Creek discharged an average net acidity load of 6 tons/day (Sta. 482). The pH ranged from 3.8 to 5.0. The South Branch of Slippery Rock Creek (Sta. 483), was alkaline during the survey, but carried high concentrations of some mine drainage indicators. Further downstream (Sta. 481) the average acidity load in Slippery Rock Creek had decreased to an average level of 5 tons/day in excess of the alkalinity. Above the confluence of Wolf Creek (Sta. 480) Slippery Rock Creek showed further decreases in the net acidity.

Wolf Creek above Grove City receives some mine drainage, but this is rapidly neutralized during travel downstream. At the mouth of Wolf Creek (Sta. 477), the net alkalinity load averaged 20 tons/day and the minimum pH was 6.9. The alkalinity carried by Wolf Creek neutralizes any acidity in Slippery Rock Creek at that point and the net alkalinity at sampling station 476 was 35 tons/day.

Muddy Creek also receives some acid mine drainage, but during the survey, Muddy Creek exhibited a pH range of 6.3 to 7.4 at its mouth and the average alkalinity concentration exceeded the acidity (Sta. 484).

Near its mouth (Sta. 175) Slippery Rock Creek had a pH range of 6.9 to 7.6, an average net alkalinity load in excess of 37 tons/day.

Little Connoquenessing Creek receives some acid mine drainage. Alkalinity loads always exceeded acidity loads during the study period, but some mine drainage was indicated by the high concentrations of iron, sulfates, and hardness (Sta. 471).

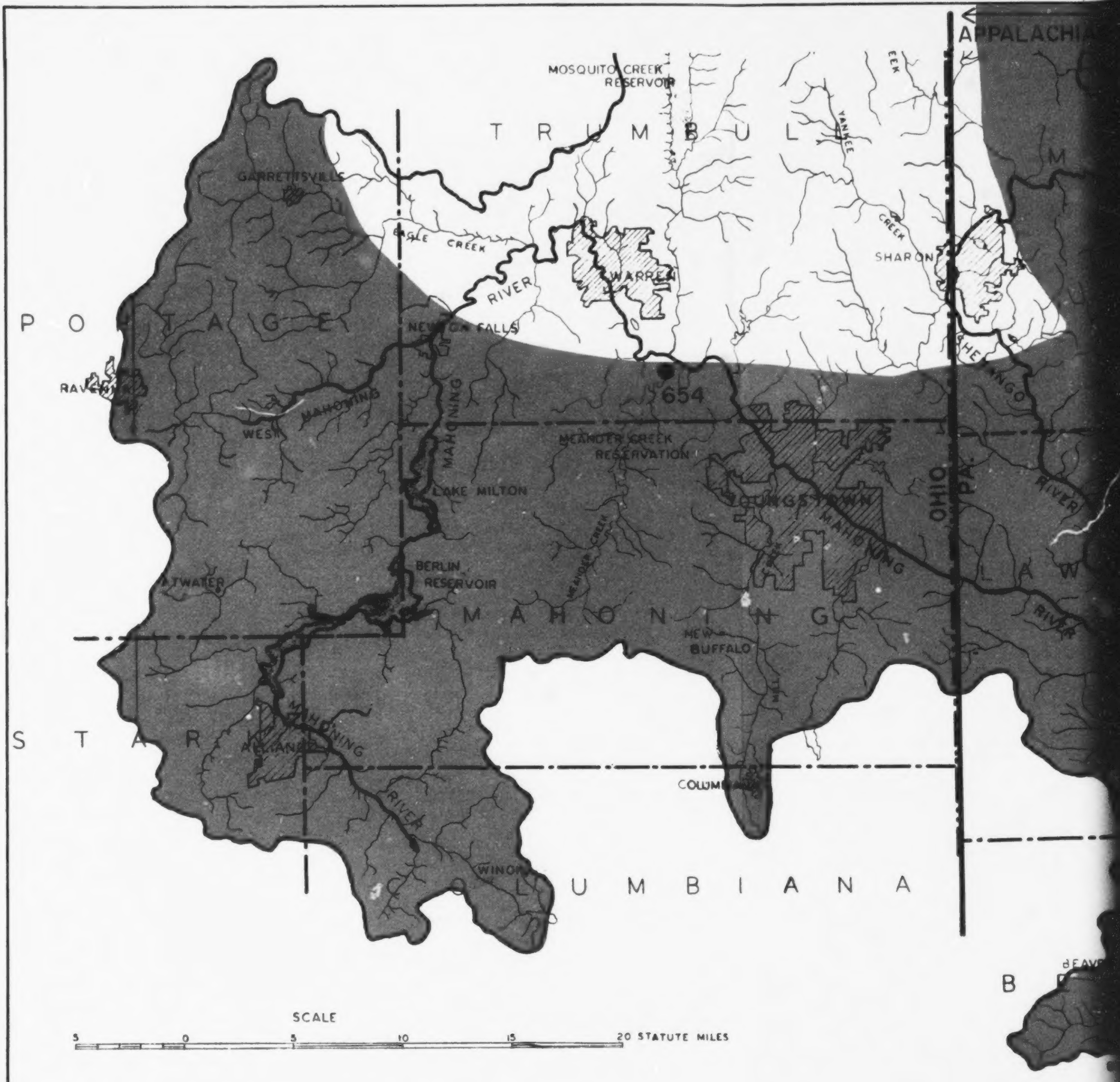
Mine drainage problems in the Beaver River basin are not limited to the Pennsylvania portion of the basin. There are several streams in Mahoning County, Ohio, though not continuously polluted by mine drainage, which have experienced washouts of acid mine water. A washout, occurring in January 1965, resulting in a fish kill of 1,600 along a tributary to Meander Creek.

Table 11 - Water Quality Data, Beaver River basin

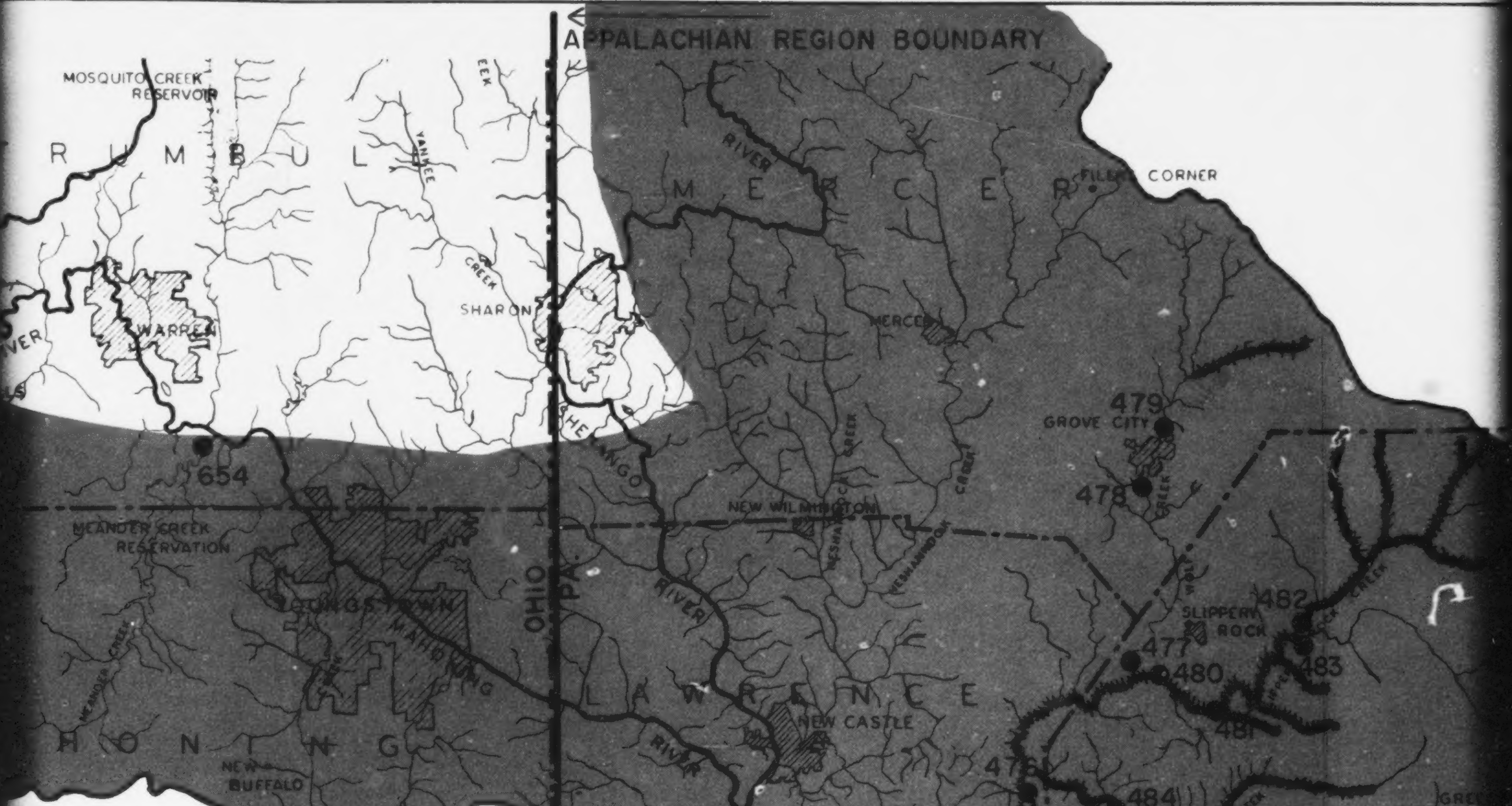
Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Total Manganese (mg/l)	Total Aluminum (mg/l)	Flow (cfs)
471	Min.		6.5	0.0	17.0	90.0	50.0	0.0	0.2	0.0	1.9
	Max.	9	7.6	34.0	53.0	326.0	560.0	4.2	1.4	3.0	340.0
	Avg.			9.3	31.3	205.1	188.0(8)*	1.3	0.8	1.0(6)	79.0
475	Min.		6.9	0.0	21.0	114.0	82.0	0.0	0.0	0.4	0.4
	Max.	9	8.3	16.0	92.0	253.0	165.0	4.2	2.3	6.0	2240.0
	Avg.			4.3	62.8	196.9	132.4	0.9	0.7	1.5(6)	513.4
476	Min.		6.6	0.0	21.0	114.0	72.0	0.0	0.0	0.0	110.0
	Max.	9	7.8	21.0	75.0	233.0	175.0	2.9	2.5	6.1	2460.0
	Avg.			6.9	45.4	176.7	127.9	0.7	0.9	1.6(6)	586.9
477	Min.		6.8	0.0	48.0	130.0	48.0	0.3	0.2	0.4	57.0
	Max.	6	7.8	25.0	79.0	236.0	140.0	0.7	0.8	1.0	222.4
	Avg.			9.8	62.0	164.8	94.8	0.5	0.4	0.6(3)	109.5
478	Min.		7.1	0.0	36.0	112.0	38.0	0.0	0.3	0.0	22.0
	Max.	9	8.5	29.0	111.0	281.0	160.0	2.4	1.3	7.5	540.0
	Avg.			10.9	68.6	184.7	100.5(8)	0.9	0.7	1.6(6)	114.4
479	Min.		6.9	15.0	22.0	66.0	33.0	0.4	0.6		55.0
	Max.	3	7.0	49.0	38.0	128.0	80.0	2.1	1.3		290.0
	Avg.			27.7	31.3	104.7	60.3	1.1	1.0		165.0
480	Min.		4.3	0.0	0.0	128.0	85.0	0.3	1.0	0.5	16.7
	Max.	9	7.2	55.0	45.0	279.0	240.0	1.8	3.1	6.9	448.2
	Avg.			19.8	15.4	201.9	176.1	0.9	2.1	2.9(6)	149.6
481	Min.		6.6	11.0	8.0	116.0	90.0	0.4	1.3		185.0
	Max.	3	7.0	27.0	15.0	180.0	140.0	1.0	2.1		356.0
	Avg.			16.7	10.7	150.7	120.0	0.7	1.7		288.7

Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Total Manganese (mg/l)	Total Aluminum (mg/l)	Flow (cfs)
482	Min.		2.7	24.0	0.0	132.0	110.0	0.2	1.0	1.8	8.9
	Max.	9	5.0	153.0	10.0	312.0	390.0	40.0	3.4	14.0	164.0
	Avg.			60.1	3.8	217.1	226.1	8.0	2.6	7.8(6)	64.5
483	Min.		6.7	0.0	22.0	116.0	73.0	0.2	1.0	0.1	2.3
	Max.	9	7.2	22.0	78.0	333.0	270.0	7.9	3.1	17.2	100.0
	Avg.			7.0	39.2	223.6	172.4	1.7	1.4	3.1(6)	31.3
484	Min.		6.1	0.0	8.0	110.0	77.0	0.1	0.4	0.0	2.0
	Max.	9	7.4	28.0	67.0	358.0	310.0	1.3	3.4	2.5	330.0
	Avg.			11.0	24.9	215.4	182.7	0.6	1.7	1.1(6)	81.3
654	Min.		7.8	0.0	32.0	113.0	115.0	0.1	0.1	0.2	0.1
	Max.	6	10.6	3.0	245.0	176.0	156.0	0.4	5.2	2.2	12.0
	Avg.			0.5	117.8	140.2	131.8	0.3	1.2	1.1(3)	3.5

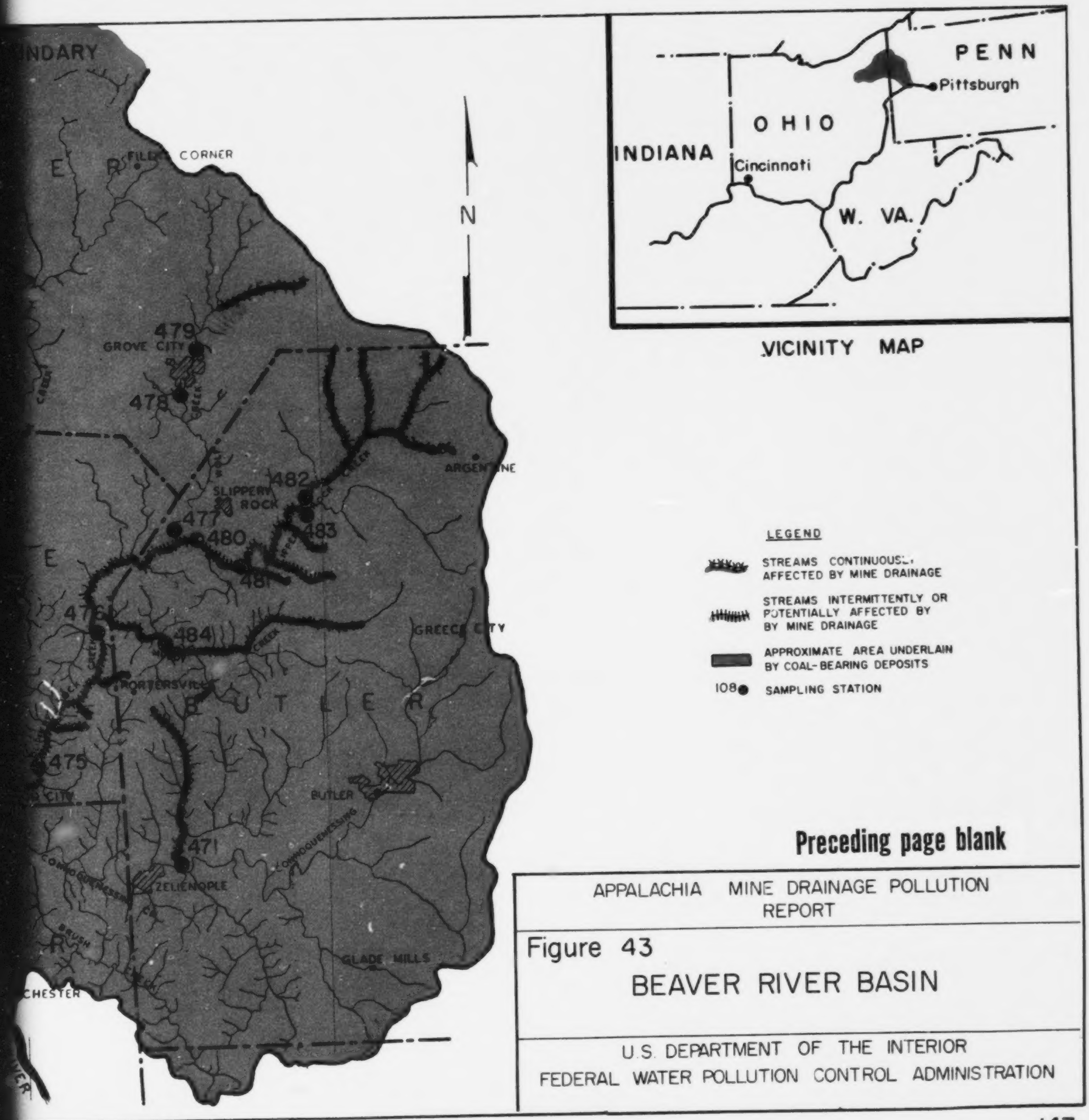
*(8) Indicates the number of samples used in averages when other than the maximum.


APPALACHIA
MOSQUITO CREEK RESERVOIR
T R U M B U L L
EEK
YANKEE
GARRETTSVILLE
EAGLE CREEK
CREEK
SHARON
WARREN
RIVER
P O R T A G E
NEWTON FALLS
RAVENNA
SHENANGO
654
WEST MAHONING
MAHONING
MEANDER CREEK RESERVATION
LAKE MILTON
YOUNGSTOWN
MAHONING
OHIO
PA.
RIVER
MEANDER CREEK
BERLIN RESERVOIR
ATWATER
M A H O N I N G
L A W
RIVER
NEW BUFFALO
S T A R K
ALLIANCE
MAHONING
RIVER
COLUMBIANA
WINONA
C O L U M B I A N A
BEAV
B
SCALE
5
0
5
10
15
20 STATUTE MILES

A


APPALACHIAN REGION BOUNDARY
MOSQUITO CREEK RESERVOIR
TRUMBULL
WARREN
SHARON
YANKEE
CREEK
MERCER
RIVER
FILERS CORNER
MERCER
479
GROVE CITY
478
654
SHENANGO
NEW WILMINGTON
NESHANNOCK CREEK
MEANDER CREEK RESERVATION
YOUNGSTOWN
MAHONING
OHIO
PA.
RIVER
LAWRENCE
SLIPPERY ROCK
482
477
480
483
481
NEW CASTLE
MAHONING
NEW BUFFALO
476
484
PORTERSVILLE
BUTLER
COLUMBIANA
475
ELLWOOD CITY
BEAVER
RIVER
BUTLER
471
ZELIENOPLE
CONNOQUENESSING
BEAVER FALLS
BEAVER
BRUSH
CREEK
GLADE MILLS
20 STATUTE MILES
ROCHESTER
BEAVER
OHIO
RIVER

B


NDARY
E
R
FILER CORNER
N
479
GROVE CITY
478
CREEK
SLIPPERY ROCK
482
483
477
480
481
476
484
ARGENTINE
GREECE CITY
PORTERSVILLE
B U T L E R
475
CITY
BUTLER
471
ZELIENOPLE
CONNOQUENESSING
BRUSH
CREEK
GLADE MILLS
CHESTER
E
PENN
Pittsburgh
OHIO
INDIANA
Cincinnati
W. VA.
VICINITY MAP
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
108● SAMPLING STATION

Preceding page blank

APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 43

BEAVER RIVER BASIN

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

Muskingum River Basin

Description

The Muskingum River basin lies in the eastern part of Ohio. It is bounded by the Scioto River drainage on the west, Lake Erie drainage on the north, and the Ohio River minor tributary drainage on the east and south. The Muskingum River is formed by the junction of its two principal tributaries, the Tuscarawas and Walhonding Rivers, at Coshocton near the center of the basin (Fig. 44). The Muskingum flows south for about 110 miles entering the Ohio River at Marietta, Ohio, 172 miles below Pittsburgh, Pennsylvania. The total drainage area of the basin is 8,040 square miles, about 20 percent of the land area of the State, and covers all or part of 27 counties. About half the area of the Muskingum basin is located in the Appalachian Region. The counties or portions of counties (11 in number) making up the western and northern boundaries of the basin are excluded.

The northern and western portions of the watershed were covered by Pleistocene age glaciers. The line of glaciation generally trends east to west from Canton to Loudonville, and thence almost directly south leaving the basin in Perry County. The glaciated area is characterized by gently rolling to flat topography. The unglaciated area is generally rugged and well dissected by drainage.

Bituminous coal reserves in the Muskingum basin are present in 21 of the 27 Ohio counties that are wholly or partly contained in the watershed, amounting to 80 percent of the area. Coal production has been reported from all but one of the 21 counties containing reserves. Recoverable coal reserves in the Muskingum River basin portion of these counties is estimated at over eight billion tons.

The Muskingum basin has a long history of coal production, and prospects for long-term continued production are excellent in view of recent industrial expansion in the area. Six of the basin counties had a cumulative coal production of over 100 million tons during the period 1800-1958. Production in 1965 in the watershed amounted to nearly 19 million tons, about 70 percent by surface mining methods (Brant and DeLong, 1960; Ohio Department Industrial Relations, 1965).

Mine Drainage Sources and Their Effect on Stream Quality

Although some mine drainage pollution occurs in each of the coal-producing counties of the basin, Tuscarawas, Coshocton, Muskingum, and Perry Counties are the most seriously affected in terms of number of streams and total length of streams affected

Preceding page blank

(Fig. 44). With very minor exceptions, all affected streams in the basin are within the Appalachian Region. A total of over 500 miles of streams in the watershed are considered to be polluted by mine drainage (Table 12).

Table 12 - Lengths of Streams Polluted by Mine Drainage
Muskingum River Basin

	Drainage Area (square miles)	Continuously Polluted (miles)	Intermittently Polluted (miles)	Total (miles)
Muskingum River	8038			
Tributaries		244	59	303
Tuscarawas River	2590			
Tributaries		154	34	188
Walhonding River	2252			
Tributaries		16	15	31
		414	+ 108	= 522

On the basis of a detailed study of the McCluney Creek watershed in Perry County, Ohio, (Fig. 44) and general knowledge of the Muskingum basin, it is estimated that there are 200 significant pollution sources originating from inactive and active coal mines. There are 29,000 acres of unreclaimed surface mined land in the Muskingum basin.

Data obtained during 1966 indicate that about 500 tons/day of mine drainage acidity is formed in surface and underground locations in the Muskingum basin. It is estimated that of the 500 tons/day of acidity formed perhaps 400 tons/day enters unneutralized into streams in the basin.

Water quality data gathered during 1966 shows that, although many smaller streams in the Muskingum watershed are affected, the large dilution and neutralization factors provided keeps mine drainage effects in the principal streams to a minimum, and other industrial pollution largely masks the quality changes caused by mine drainage.

The following fish kills resulting from acid mine drainage were reported in the Muskingum River basin during 1966:

Date	County	Watershed	Number of Fish Killed
8/12/66	Perry	Jonathan Creek	5,000
8/21/66	Coshocton	Mill Creek	3,061
8/31/66	Tuscarawas	Sugar Creek	50,670
9/22/66	Muskingum	Muskingum River	20,860

Most of the coal mine drainage flowing into the Tuscarawas River enters in the reach between Massillion and Newcomerstown. Industrial pollution originating in the Akron area affects the Tuscarawas River to such a degree that the influence of the mine drainage that enters the river below Massillion is not easily recognizable. The effect of mine drainage is, however, reflected in loadings of mine drainage pollution indicators. The average sulfate loading was 142 tons/day at station 719 above Massillion and 250 tons/day at station 727 above Newcomerstown. The average iron loadings were 0.3 tons/day and 2 tons/day at these respective stations.

The small amount of mine drainage entering the Walhonding River is contributed by tributaries entering in the lower 10 miles of the river. These sources and tributaries entering the Muskingum immediately below Coshocton do not significantly affect the quality of the Muskingum, but are evidenced by increased loadings of mine drainage indicators, such as sulfate, hardness, and iron.

In the lower Muskingum basin, Moxahala Creek and its tributaries in Perry and Muskingum Counties are the most seriously polluted streams from acid mine drainage in the Muskingum basin. Ninety miles of streams in this small watershed are affected. A 1963 survey showed Moxahala Creek to be highly acidic over most of its length and discharging 8 tons/day of acidity to the Muskingum River. Readings of pH as low as 2.7 were observed in stream waters during the survey. Limited field work conducted during 1966 indicates there may be more than 200 significant point sources of mine drainage polluting the streams of the Moxahala watershed.

Most of the coal mine drainage flowing into the Tuscarawas River enters in the reach between Massillion and Newcomerstown. Industrial pollution originating in the Akron area affects the Tuscarawas River to such a degree that the influence of the mine drainage that enters the river below Massillion is not easily recognizable. The effect of mine drainage is, however, reflected in loadings of mine drainage pollution indicators. The average sulfate loading was 142 tons/day at station 719 above Massillion and 250 tons/day at station 727 above Newcomerstown. The average iron loadings were 0.3 tons/day and 2 tons/day at these respective stations.

The small amount of mine drainage entering the Walhonding River is contributed by tributaries entering in the lower 10 miles of the river. These sources and tributaries entering the Muskingum immediately below Coshocton do not significantly affect the quality of the Muskingum, but are evidenced by increased loadings of mine drainage indicators, such as sulfate, hardness, and iron.

In the lower Muskingum basin, Moxahala Creek and its tributaries in Perry and Muskingum Counties are the most seriously polluted streams from acid mine drainage in the Muskingum basin. Ninety miles of streams in this small watershed are affected. A 1963 survey showed Moxahala Creek to be highly acidic over most of its length and discharging 8 tons/day of acidity to the Muskingum River. Readings of pH as low as 2.7 were observed in stream waters during the survey. Limited field work conducted during 1966 indicates there may be more than 200 significant point sources of mine drainage polluting the streams of the Moxahala watershed.

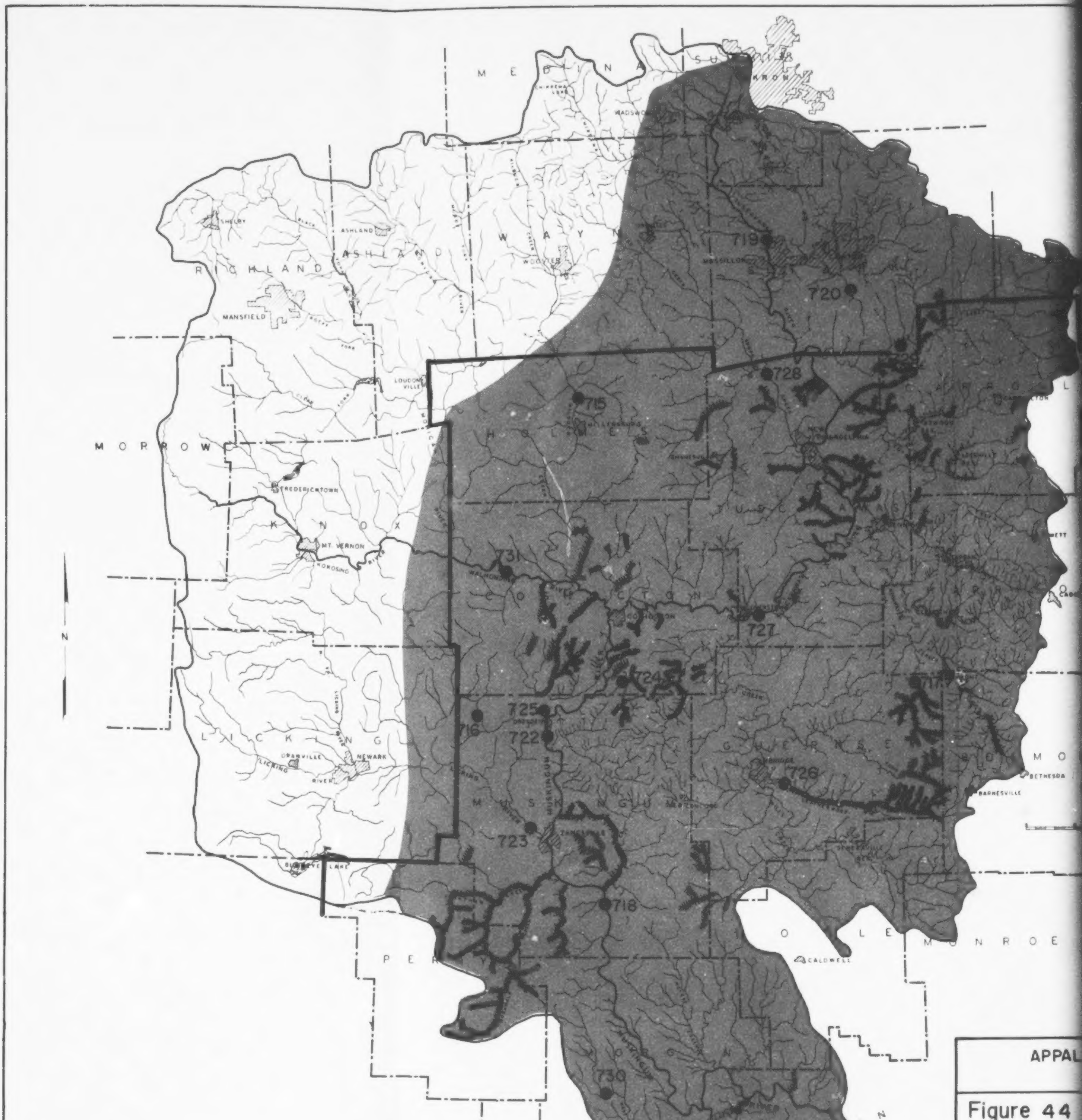
Table 13 - Water quality data, Muskingum River basin

Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Total Manganese (mg/1)	Total Aluminum (mg/1)	Flow (cfs)
1715	Min.	9	7.3	0.0	93.0	126.0	52.0	0.2	0.2	0.7	18.1
	Max.		7.7	10.0	201.0	228.0	136.0	3.8	1.0	3.1	687.0
	Avg.			1.3(8)*	161.4(8)	162.1(8)	67.9	1.7	0.5	1.6(6)	211.0
1716	Min.	9	7.1	0.0	69.0	106.0	9.0	0.4	0.1	0.6	10.0
	Max.		7.6	24.0	194.0	156.0	35.0	0.7	0.3	1.3	38.0
	Avg.			4.1	97.9	132.2	21.3(8)	0.6	0.2	0.9(6)	21.0
1717	Min.	12	6.4	0.0	26.0	49.0	25.0	0.4	0.1	0.7	0.0
	Max.		7.7	28.0	148.0	236.0	105.0	5.9	7.2	1.3	150.4
	Avg.			10.6	83.4	141.5	67.7	1.3	1.4	1.0(5)	45.1
1718	Min.	9	6.8	0.0	74.0	327.0	160.0	1.0	0.2	1.6	890.0
	Max.		8.0	39.0	120.0	432.0	240.0	2.5	3.3	3.4	3027.0
	Avg.			12.7	100.1	390.2	190.3	1.6	1.3	2.3(6)	1573.6
1719	Min.	14	6.3	16.0	79.0	295.0	35.0	0.2	0.0	0.4	75.0
	Max.		8.3	129.0	216.0	3000.0	2500.0	3.6	0.3	19.6	847.0
	Avg.			64.5	145.3	1752.4	443.8(13)	1.0(13)	0.1(13)	4.3(6)	254.9
1720	Min.	15	7.0	0.0	98.0	198.0	20.0	0.0	0.3	0.0	62.3
	Max.		7.8	99.0	302.0	474.0	500.0	5.0	1.4	1.6	500.0
	Avg.			13.4	302.0	292.9	240.9	2.1	0.9	0.9(7)	144.1
1721	Min.	9	6.9	0.0	89.0	222.0	132.0	0.2	0.1	0.5	980.0
	Max.		7.9	45.0	127.0	428.0	215.0	1.2	0.6	2.2	2600.0
	Avg.			11.9	105.6	346.8	179.8	0.5	0.3	0.9(6)	1647.2
1722	Min.	9	7.0	0.0	12.0	126.0	110.0	0.5	0.3	1.0	800.0
	Max.		8.6	32.0	148.0	428.0	220.0	2.3	1.2	2.0	2410.0
	Avg.			7.7	104.1	343.4	168.1	1.0	0.8	1.4(6)	1318.0

Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Total Manganese (mg/l)	Total Aluminum (mg/l)	Flow (cfs)
1723	Min.	9	7.2	0.0	16.0	133.0	56.0	0.4	0.2	0.0	87.0
	Max.		8.1	43.0	187.0	420.0	425.0	1.4	1.1	2.2	348.0
	Avg.			10.8	140.0	216.2	107.8	0.9	0.5	1.0(6)	167.4
1724	Min.	9	6.7	0.0	0.0	140.0	110.0	0.4	0.9	0.6	30.0
	Max.		7.5	28.0	86.0	375.0	310.0	10.8	5.4	4.9	264.0
	Avg.			7.0	61.9	273.3	253.9	2.4	2.2	2.1(6)	77.8
1725	Min.	9	6.8	0.0	47.0	140.0	60.0	0.2	0.2	0.5	28.0
	Max.		7.4	82.0	89.0	263.0	223.0	1.8	13.8	2.0	75.5
	Avg.			18.4	73.9	199.8	122.8	0.6	2.9	1.2(6)	46.7
1726	Min.	4	6.9	0.0	90.0	431.0	440.0	0.9	0.8	0.3	0.0
	Max.		7.1	27.0	131.0	624.0	565.0	1.4	1.2	1.4	0.0
	Avg.			11.5	108.5	548.8	503.8	1.2	1.0	0.9(3)	0.0
1727	Min.	12	6.5	0.0	41.0	242.0	110.0	0.5	0.8	0.7	295.0
	Max.		8.6	68.0	150.0	804.0	320.0	3.9	2.0	5.2	9800.0
	Avg.			17.9	80.5	516.4	194.6	2.2	1.3	2.0(5)	2357.6
1728	Min.	14	6.9	0.0	38.0	168.0	120.0	0.4	0.4	0.1	9.1
	Max.		8.2	43.0	123.0	429.0	4750.0	2.0	12.2	2.0	830.0
	Avg.			11.1	83.6	319.2	572.7	1.0	3.3	1.1(7)	145.8
1729	Min.	15	6.9	0.0	23.0	83.0	68.0	0.2	0.2	0.7	28.0
	Max.		8.1	54.0	137.0	440.0	200.0	4.5	1.5	2.2	1420.0
	Avg.			10.5	85.2	211.1	123.9	2.1	0.7	1.4(7)	272.5
1730	Min.	8	7.5	0.0	151.0	44.0	25.0	0.0	0.2	0.0	0.1
	Max.		8.2	42.0	224.0	170.0	54.0	0.5	0.7	0.8	12.3
	Avg.			7.1	182.3	117.0	39.4	0.2	0.3	0.5(5)	3.1

Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Total Manganese (mg/1)	Total Aluminum (mg/1)	Flow (cfs)
1731	Min.		7.1	0.0	105.0	106.0	40.0	0.2	0.0	0.6	281.0
	Max.	9	8.2	56.0	158.0	209.0	75.0	1.4	0.5	2.5	2480.0
	Avg.			6.2	137.7	164.9	57.7	0.7	0.2	1.2(6)	941.0

*(8) Indicates the number of samples used in averages when other than the maximum.


M E D I N A
S U M M I T
AKRON
CHIPPEWA LAKE
WADSWORTH
R I C H L A N D
A S H L A N D
W A Y N E
SHELBY
ASHLAND
WOOSTER
MANSFIELD
MASSILLON
LOUDONVILLE
M O R R O W
K N O X
FREDERICKTOWN
MT. VERNON
KOKOSING
L I C K I N G
GRANVILLE
NEWARK
LICKING RIVER
BUCKEYE LAKE
H O L M E S
MILLERSBURG
C O S H O C T O N
WALHONDING
COSHOCTON
M U S K I N G U M
ZANESVILLE
MUSKINGUM
P E R R Y
M O R G A N
A T H E N S
W
N
MARIETTA
OHIO RIVER
N O B L E
CALDWELL
M O N R O E
G U E R N S E Y
CAMBRIDGE
BETHESDA
BARNESVILLE
CARROLL
NEW PHILADELPHIA
N
715
716
717
718
719
720
721
722
723
724
725
726
727
728
730
731

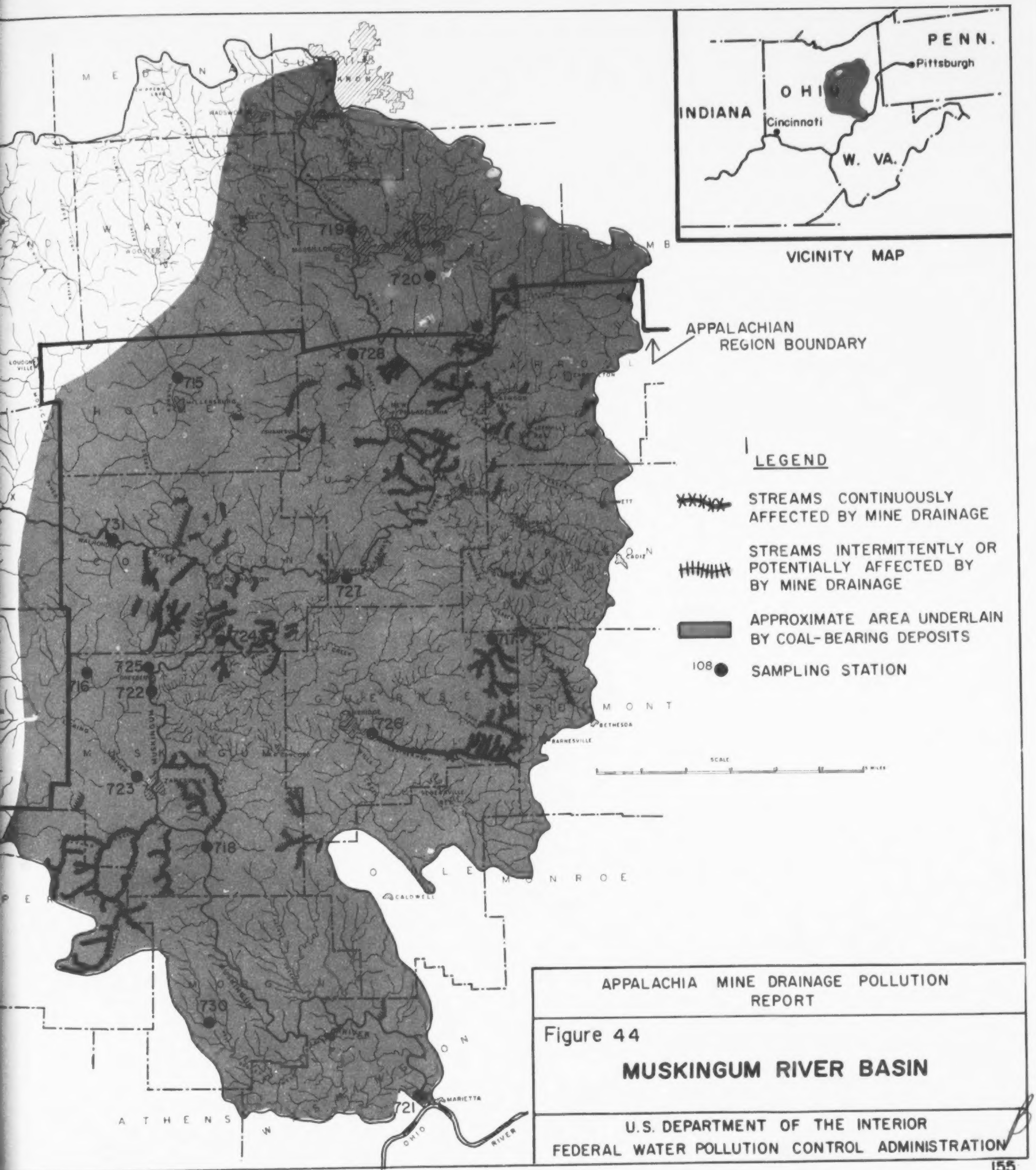
APPAL

Figure 44

MU

U.S

FEDERAL WA


PENN.
Pittsburgh
OHIO
INDIANA
Cincinnati
W. VA.
VICINITY MAP
APPALACHIAN REGION BOUNDARY
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
108 SAMPLING STATION
SCALE
MEDINA
SUMMIT
WAYNE
HOLMES
CARROLL
TUSCARAWAS
HARRISON
COSHOCTON
GUERNSEY
BELMONT
MUSKINGUM
NOBLE
MONROE
MORGAN
WASHINGTON
ATHENS
PERRY
LOUDONVILLE
CADIZ
BETHESDA
BARNESVILLE
CALDWELL
MARIETTA
OHIO RIVER
MUSKINGUM
719
720
728
715
731
727
724
725
722
716
717
726
723
718
730
721

APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 44

MUSKINGUM RIVER BASIN

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

Hocking River Basin

Description

The Hocking River basin embraces an area of 1200 square miles located in the hill section of southeastern Ohio (Fig. 45). The basin is bounded on the north by the Muskingum River drainage basin, on the west by the Scioto River basin, and on the south by the Raccoon Creek, Leading Creek, and Shade River drainage basins. The basin includes portions of Fairfield, Perry, Hocking, Morgan, Athens, Meigs, and Washington Counties. Of the counties in the Hocking River basin, all but Fairfield County, in the northwest corner of the watershed, are in the Appalachian Region.

With the exception of the uppermost part in Fairfield, Perry and Hocking Counties, the Hocking basin lies in the unglaciated portion of Ohio. Generally, the valleys are narrow and the hillsides are steep and abrupt. The divides are ridge-like, separating streams arranged generally in a dendritic pattern. The Hocking River heads in Fairfield County in the northwestern portion of the basin. The stream extends approximately 95 miles in a relatively straight line in a southeastward direction to its confluence with the Ohio River, about 15 miles below Parkersburg, West Virginia. The river has an average gradient of 4.6 feet per mile. Principal tributaries to the Hocking watershed include Rush Creek, Sunday Creek, Monday Creek, and Federal Creek.

Bituminous coal reserves in the Hocking River basin are present in five of the six counties that make up the watershed, amounting to three-quarters of the area. Coal production has been reported in all of the counties containing reserves. Production in 1962 amounted to more than 900,000 tons and increased to over 1.6 million in 1965. Surface mine operations accounted for approximately 80 percent of the total coal production figures in 1965.

The recoverable reserve of coal within the boundaries of this drainage area is estimated at over one billion tons.(Brant and DeLong, 1960; Ohio Department of Industrial Relations, 1965). This tonnage represents substantial potential for continued and expanded coal production in the Hocking River basin.

Mine Drainage Sources and Their Effect on Stream Quality

During a detailed study of 74 square miles in the Sunday Creek watershed (Fig. 45), 20 mine drainage sources were examined and 15 drainages were sampled. The total number of sources is not known. There are presently 4,000 acres of unreclaimed surface-mined land in the basin.

Preceding page blank

Calculation of sulfate loadings for 1955-1959, 1962, 1963 and 1965 (Fig. 46) at Athens, Ohio, indicates that an average of about 335 tons/day of acidity are formed in the Hocking basin. Of this total, it is estimated that 200 tons/day enters streams in the basin unneutralized.

The Hocking River basin contains 364 miles of streams significantly polluted by coal mine drainage, 223 miles of which are continuously polluted and 141 miles of which are intermittently polluted. The principal problem areas are found in Athens, Hocking, and Perry Counties (Fig. 45).

Major tributaries to the Hocking River polluted by coal mine drainage are Rush Creek, Monday Creek, Sunday Creek, and Federal Creek. At its midpoint (Sta. 696) Monday Creek carried an acidity load of 5.6 tons/day, had a pH range of 3.1 to 3.6, and had high concentrations of sulfate, metals and hardness. At its mouth (Sta. 690) the acidity load in Monday Creek increased to 19 tons/day, the pH ranged from 2.8 to 3.3, and other mine drainage indicators were present in high concentrations.

At its confluence with Sunday Creek (Sta. 698), the West Branch of Sunday Creek carried an acidity load of 4.2 tons/day, exhibited a pH range of from 2.9 to 4.2, and had high concentrations of sulfate, metals, and hardness. Sunday Creek carried an acidity load of 13 tons/day at its mouth (Sta. 691) and had high concentrations of mine drainage indicators.

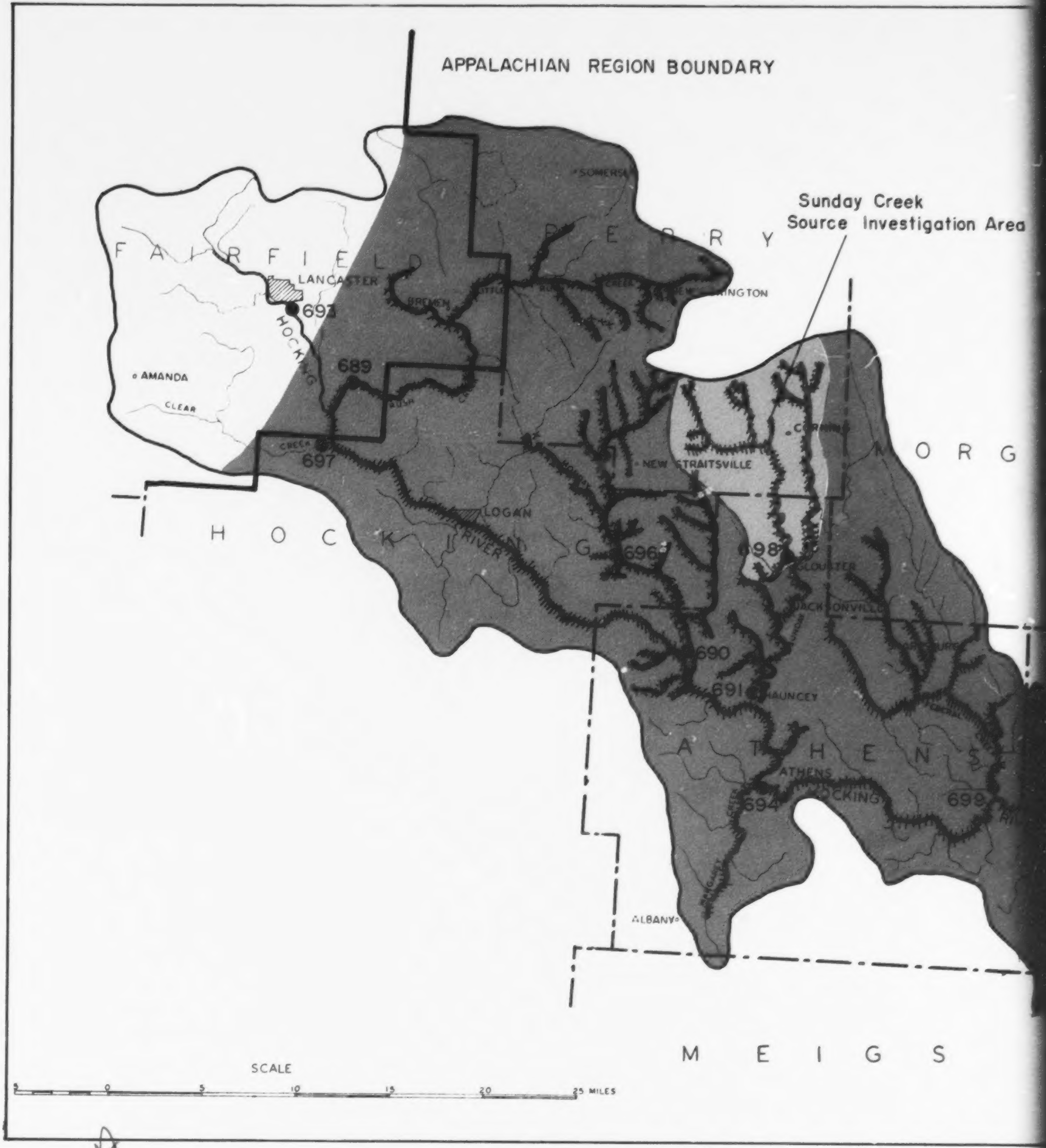
Rush and Federal Creeks receive mine drainage throughout their watersheds, but are alkaline at their mouths. The level of mine drainage pollution in these streams is indicated by the concentrations of sulfate, metals and hardness as measured at stations 689 and 699 (Fig. 45).

Table 14 - Water quality data, Hocking River basin

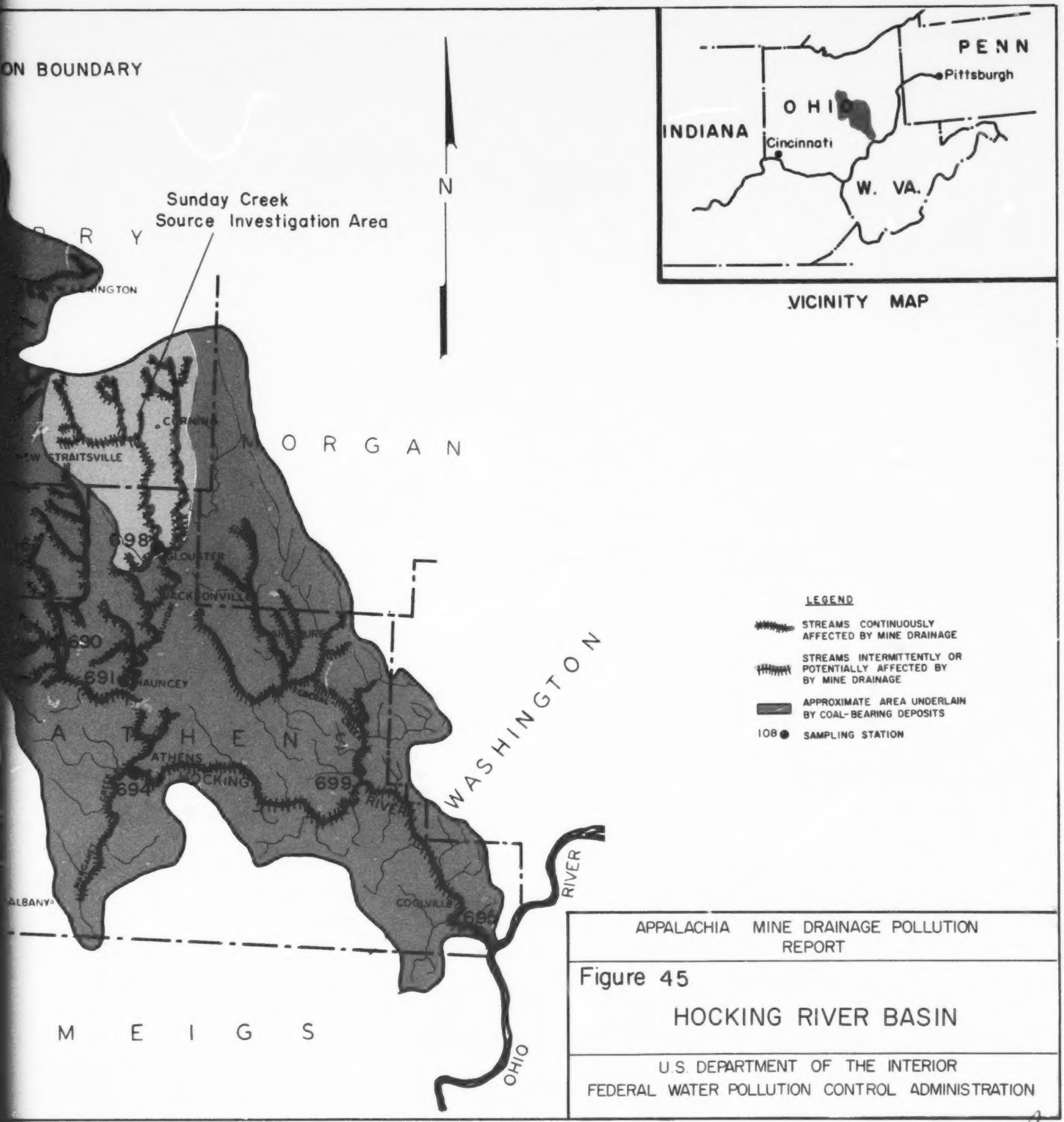
Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Total Manganese (mg/l)	Total Aluminum (mg/l)	Flow (cfs)
689	Min.		5.8	0.0	10.0	75.0	75.0	0.2	1.6	0.0	36.0
	Max.	6	7.4	35.0	72.0	545.0	450.0	6.6	13.8	11.1	870.0
	Avg.			11.0	39.2	324.0	243.3	2.1	8.0	4.4	185.3
690	Min.		2.8	175.0	0.0	219.0	260.0	4.8	8.3	25.7	8.0
	Max.	6	3.3	597.0	0.0	1480.0	875.0	43.2	12.2	138.9	43.5
	Avg.			438.8	0.0	571.8	572.5	20.2	10.1	64.5	16.6
691	Min.		2.6	0.0	0.0	110.0	95.0	3.5	0.0	0.9	10.7
	Max.	6	6.2	712.0	32.0	780.0	1175.0	168.0	13.8	86.2	90.0
	Avg.			400.3	5.3	562.0	503.3	64.9	9.0	44.8	26.1
693	Min.		6.5	0.0	55.0	58.0	14.0	0.4	0.0	0.0	10.0
	Max.	6	7.9	9.0	296.0	290.0	120.0	7.6	0.3	10.6	304.0
	Avg.			1.5	223.3	180.2	74.8	2.2	0.2	4.3	62.1
694	Min.		6.6	0.0	30.0	104.0	80.0	0.3	1.3	0.9	92.0
	Max.	6	7.6	28.0	113.0	460.0	340.0	4.8	13.8	20.7	7600.0
	Avg.			5.3	74.7	368.0	236.7	1.7	5.1	5.3	1398.3
695	Min.		6.4	0.0	24.0	94.0	85.0	0.3	0.2	1.5	120.0
	Max.	6	7.7	25.0	90.0	430.0	340.0	6.2	4.4	6.8	7500.0
	Avg.			6.8	71.5	307.8	201.7	1.7	1.0	3.2	1417.5
696	Min.		3.1	107.0	0.0	455.0	164.0	3.6	8.2	6.4	2.2
	Max.	6	3.6	364.0	0.0	1044.0	580.0	12.0	13.8	66.6	15.0
	Avg.			248.7	0.0	675.0	419.0	6.7	11.0	27.1	7.6

Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Total Manganese (mg/1)	Total Aluminum (mg/1)	Flow (cfs)
697	Min.		7.0	0.0	84.0	64.0	24.0	0.2	0.0	0.0	13.0
	Max.	6	8.2	0.0	187.0	267.0	37.0	5.3	1.6	7.9	312.0
	Avg.			0.0	143.7	149.6(5)*	31.7	1.2	0.6	1.9	66.3
698	Min.		2.9	125.0	0.0	250.0	330.0	16.8	3.9	3.7	3.5
	Max.	6	4.2	446.0	0.0	945.0	1225.0	72.0	13.8	123.8	12.2
	Avg.			315.8	0.0	696.0	740.8	49.7	11.0	54.6	5.7
699	Min.		5.0	0.0	1.0	168.0	120.0	0.0	0.3	0.2	0.0
	Max.	6	7.7	100.0	142.0	620.0	265.0	1.0	3.3	6.7	110.0
	Avg.			23.5	86.2	323.8	210.8	0.6	1.3	3.5	18.6

*(5) Indicates the number of samples used in averages when other than the maximum.


APPALACHIAN REGION BOUNDARY
Sunday Creek
Source Investigation Area
FAIRFIELD
PERRY
MORG
HOCKING
ATHENS
MEIGS
SOMERSET
LANCASTER
693
HOCKING
BREMEN
NEW LEXINGTON
689
AMANDA
CLEAR
RUSH
697
CREEK
NEW STRAITSVILLE
CORNING
LOGAN
RIVER
696
698
GLOUSTER
JACKSONVILLE
690
691
CHAUNCEY
ATHENS
694
HOCKING
699
RIVER
ALBANY
SCALE
5
0
5
10
15
20
25 MILES

A


ON BOUNDARY
Sunday Creek
Source Investigation Area
N
R Y
INGTON
CORNING
NEW STRAITSVILLE
M O R G A N
698
GLOUSTER
JACKSONVILLE
690
691
CHAUNCEY
A T H E N S
ATHENS
HOCKING
RIVER
694
699
696
COOLVILLE
ALBANY
WASHINGTON
RIVER
OHIO
M E I G S
PENN
Pittsburgh
OHIO
INDIANA
Cincinnati
W. VA.
VICINITY MAP
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
108 ● SAMPLING STATION

APPALACHIA MINE DRAINAGE POLLUTION
REPORT

Figure 45

HOCKING RIVER BASIN

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

Preceding page blank

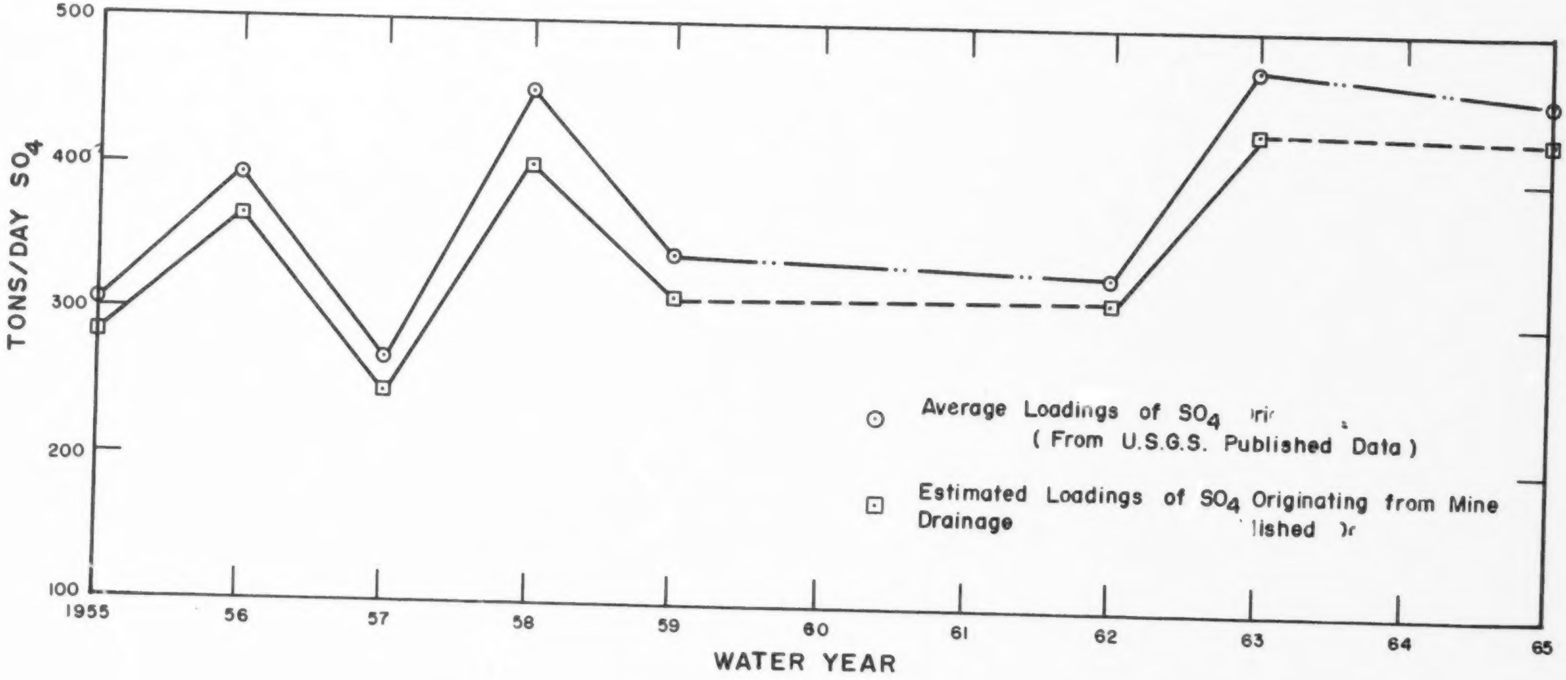


Figure 46. Average loads of total sulfate and sulfate considered to orginate from coal mine drainage carried by the Hocking River at Athens, Ohio

Little Kanawha River

Description

The Little Kanawha River basin embraces 2,309 square miles of west-central West Virginia, lies entirely within the State, and entirely within Appalachia. The basin is bounded on the south by the Kanawha River basin, on the west by the Ohio River, on the north by the Middle Island Creek basin, and on the east by the Monongahela River basin. The basin contains all or part of 12 West Virginia counties (Fig. 47). The topography of the Little Kanawha basin is rugged throughout with elevations in the headwaters reaching approximately 2,200 feet. The normal pool elevation at the mouth of the basin is 572 feet, giving a total relief of about 1,630 feet.

Bituminous coal reserves are present in seven of the 12 counties which are wholly or partly contained in the basin (Fig. 47). The area underlain by mineable coal reserve amounts to about 60 percent of the total land area of the watershed. The recoverable coal reserve of the Little Kanawha River basin portion of these counties is estimated to be about two billion tons.

Although the watershed contains an appreciable coal reserve, the resource has not been extensively tapped. The coal removed over the years in this area has been mostly for domestic uses. Development of the reserves has been hindered by mining difficulty, high sulfur content, and variable thickness. Coal production in 1965 amounted to over one million tons, predominantly from underground mining in Gilmer County (West Virginia Department of Labor and Industry, 1965).

Mine Drainage Sources and Their Effect on Stream Quality

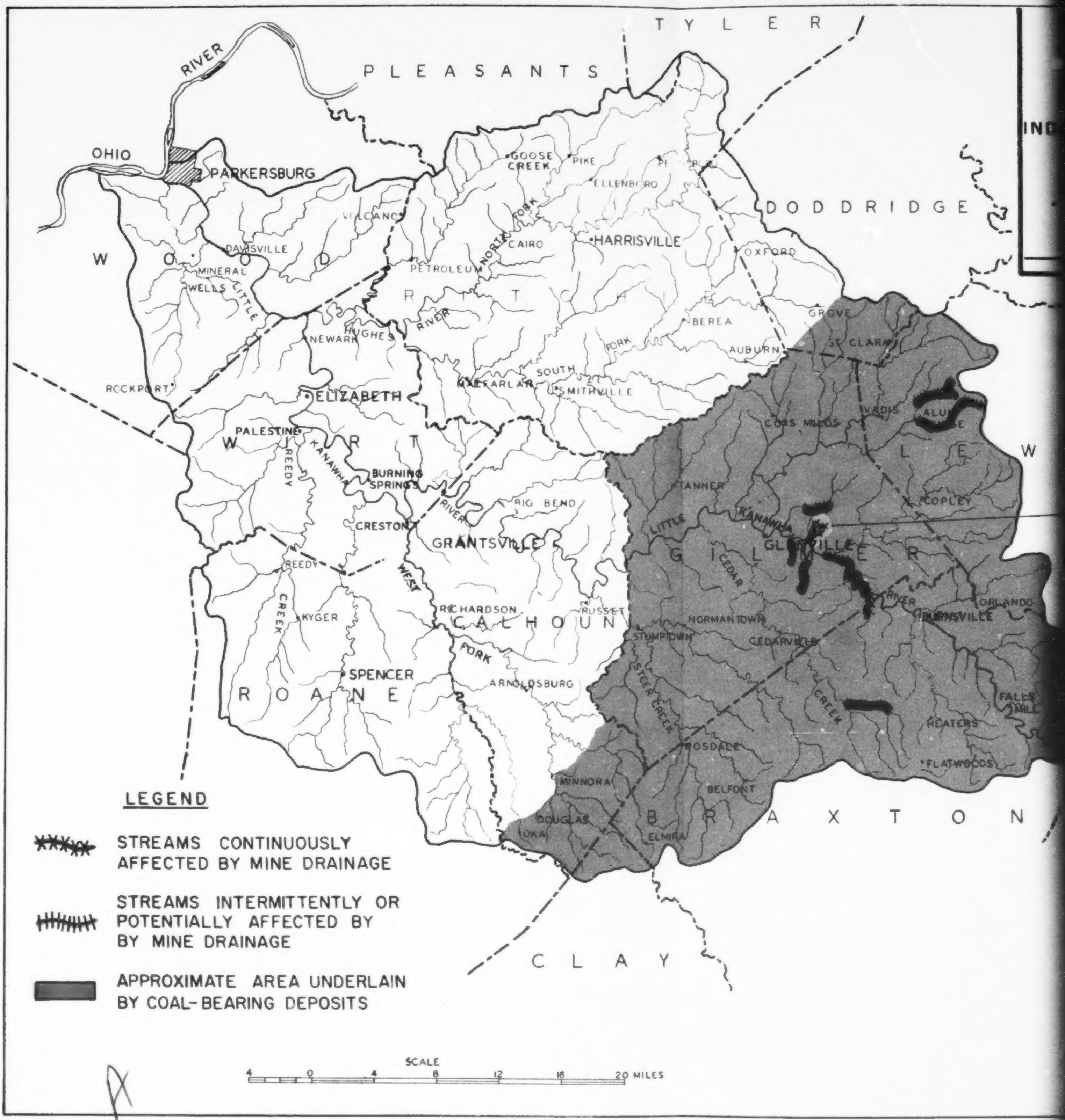
During detailed study of an area in the Lynch Run watershed (Fig. 47) 19 mine drainage sources were examined and 17 drainages were sampled and measured. The total number of sources is not known. A total of 4,000 acres of unreclaimed surface-mined land presently exists in the basin. It is estimated that 10 tons/day of acidity enters streams in the basin.

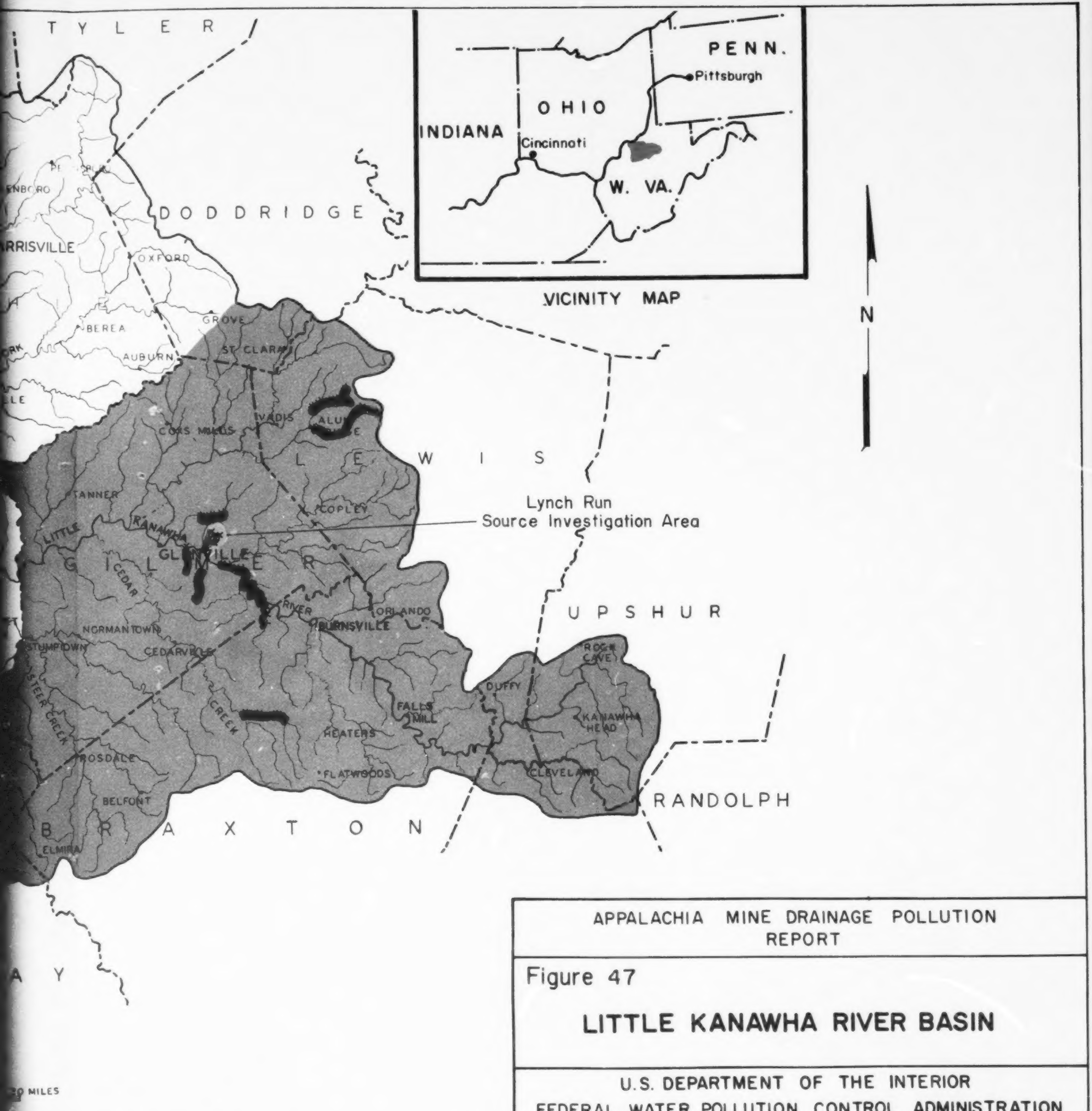
Water quality analyses of stream waters shows mine drainage to be present in the Little Kanawha River in its upper portions (Fig. 47). The Little Kanawha River is intermittently polluted by

Preceding page blank

mine drainage downstream to about Glenville in Gilmer County. The principal mine drainage contributors to the main stem are minor tributaries that enter the river between the Gilmer-Braxton county line and Glenville, West Virginia. Mine drainage pollution also occurs on an intermittent basis in portions of the headwaters areas of Leading and Cedar Creeks, tributaries to the Little Kanawha in Gilmer County.

About five miles of the Little Kanawha River is considered to be intermittently polluted by mine drainage. A total of 25 miles of tributary streams are considered to be polluted by mine drainage, 20 miles on an intermittent basis.


TYLER
PLEASANTS
RIVER
OHIO
PARKERSBURG
GOOSE CREEK
PIKE
ELLENBORO
VULCAN
NORTH FORK
CAIRO
HARRISVILLE
DODDRIDGE
WOOD
DAVISVILLE
MINERAL WELLS
LITTLE
PETROLEUM
RITCHIE
OXFORD
GROVE
ST CLARA
BEREA
AUBURN
NEWARK
HUGHES
RIVER
FORK
SOUTH
SMITHVILLE
MACFARLAN
ROCKPORT
ELIZABETH
PALESTINE
WIRT
REEDY
KANAWHA
BURNING SPRINGS
COXS MILLS
VADIS
LEWIS
W
TANNER
COPLEY
BIG BEND
RIVER
CRESTON
LITTLE
KANAWHA
GLENVILLE
GILMER
GRANTSVILLE
CEDAR
REEDY
WEST
RICHARDSON
RUSSET
RIVER
ORLANDO
BURNSVILLE
CREEK
KYGER
CALHOUN
NORMANTOWN
STUMPTOWN
CEDARVILLE
FORK
SPENCER
ROANE
ARNOLDSBURG
STEER CREEK
CREEK
FALLS MILL
HEATERS
ROSDALE
FLATWOODS
MINNORA
BELFONT
DOUGLAS
OKA
ELMIRA
BRAXTON
CLAY
IND
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
SCALE
4 0 4 8 12 16 20 MILES
A


TYLER
DODDRIDGE
ENBORO
RRISVILLE
OXFORD
GROVE
BEREA
AUBURN
ST. CLARA
VADIS
ALUM
COX MILLS
LEWIS
TANNER
COPLEY
LITTLE KANAWHA
GLENVILLE
GILMER
CEDAR
RIVER
ORLANDO
BURNSVILLE
UPSHUR
NORMANTOWN
STUMPTOWN
CEDARVILLE
ROCK CAVE
DUFFY
FALLS MILL
STEER CREEK
CREEK
KANAWHA HEAD
HEATERS
ROSDALE
FLATWOODS
CLEVELAND
BELFONT
RANDOLPH
BRAXTON
ELMIRA
AY
20 MILES
Lynch Run
Source Investigation Area
PENN.
Pittsburgh
OHIO
INDIANA
Cincinnati
W. VA.
VICINITY MAP
N

APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 47

LITTLE KANAWHA RIVER BASIN

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

B

Kanawha River Basin

Description

The Kanawha River basin spans the entire width of south-central West Virginia, includes the west-central portion of Virginia, and the northwestern part of North Carolina. It is bounded on the north by the Little Kanawha and Monongahela River basins, on the east by the Potomac and Roanoke River basins, on the south by the Pee Dee River basin, and on the west by the Tennessee, Big Sandy and Guyandotte River basins. The total drainage area of the Kanawha basin is 12,300 square miles, 8,450 of which are in West Virginia, 3,080 in Virginia, and 770 in North Carolina. The basin is entirely within the Appalachian Region (Fig. 48).

The Kanawha River is formed by the confluence of the New and Gauley Rivers at Gauley Bridge, West Virginia. From the point of origin it flows northwesterly for 95 miles to its junction with the Ohio River at Point Pleasant, West Virginia, 266 river miles below Pittsburgh. The main tributaries comprising the Kanawha River system are the Elk, Gauley, New and Greenbrier Rivers.

The entire Kanawha basin is mountainous in character, although the upper and lower portions comprise two contrasting types of topography. Rounded hills and wide valleys characterize the lower basin, and high mountains and deep gorges characterize the upper basin. Elevations range from a high of about 5,000 feet in the Blue Ridge Mountains of North Carolina to 538 feet at the mouth of the Kanawha River, giving a maximum relief of about 4,500 feet.

Bituminous coal deposits underlie 19 of the 21 West Virginia counties that are wholly or partly contained in the Kanawha River basin. Coal production has been reported for all but one of these 19 counties.

The recoverable coal reserve in the Kanawha basin, underlying about 70 percent of the total area of the watershed, amounts to an estimated 23 billion tons. There are no coal deposits in the Virginia and North Carolina portions of the basin.

The Kanawha basin coal fields were developed very early, and have been very large producers in the history of the coal mining industry in West Virginia. Three of the counties produced more than 500 million tons of coal in the period 1883-1965. Coal production in the Kanawha basin in 1965 amounted to over 46 million tons. The principal producing counties were Boone, Fayette, Kanawha, and Raleigh. (West Virginia Department of Labor and Industry, 1965).

Preceding page blank

Mine Drainage Sources and Their Effect on Stream Quality

During detailed investigation of the Heizer Creek and Cabin Creek watersheds (Fig. 48) 71 mine drainage sites were examined and 22 drainages were sampled. The total number of mine drainage sources in the Kanawha basin is not known. There are 64,000 acres of unreclaimed surface-mined land in the basin. It is estimated that 350 tons/day of unneutralized acidity reaches streams in the basin.

Some stream pollution from mine drainage in the basin occurs in nearly all coal mining areas, but it is particularly prevalent in Kanawha, Boone, and Nicholas Counties (Fig. 48). The Coal and Gauley River systems that traverse these counties contain 333 and 385 miles of mine drainage polluted streams, respectively (Table 15).

Significant mine drainage pollution occurs in the New, Gauley, Elk, Coal, and Pocatalico Rivers. Generally, serious pollution exists in the headwater areas of these drainages and in small tributaries to these streams. Pollution in the main streams is intermittent and water quality is not severely degraded. Significant intermittent pollution also occurs in Cabin Creek and Paint Creek, tributaries to the Kanawha River in southern Kanawha County.

Table 15 - Lengths of Streams Polluted by Mine Drainage
Kanawha River Basin

	Drainage Area (Square Miles)	Continuously Polluted(Miles)		Intermittently Polluted(Miles)		Total
Kanawha River	12,240					
Tributaries				95		95
Pocatalico River		85		90		175
Tributaries		20				20
Coal River		31		6		37
Tributaries		63				63
Little Coal River		104		18		122
Tributaries		52				52
Elk River		96				96
Tributaries		20		14		34
Gauley River		60		67		127
Tributaries		87				87
New River		133		165		298
Tributaries		108		89		197
		859	+	544	=	1,403

In the New River basin, the Bluestone River (Sta. 26, Fig. 48), Piney (Sta. 16) and Coal Creeks, and a number of small tributaries to the New River are affected.

The Gauley River receives intermittent mine drainage at various locations along its length (Fig. 48). Although the Gauley River is not intensely polluted, this drainage area contains more miles of affected streams than the other tributary watersheds in the Kanawha River basin.

The Elk River, water supply source for Charleston, West Virginia intermittently receives mine drainage from the Birch River in northern Nicholas County, Buffalo Creek in Clay County, and Blue Creek in Kanawha County. Mine drainage also occurs in the Elk River from mining areas in the Webster Springs area, Webster County.

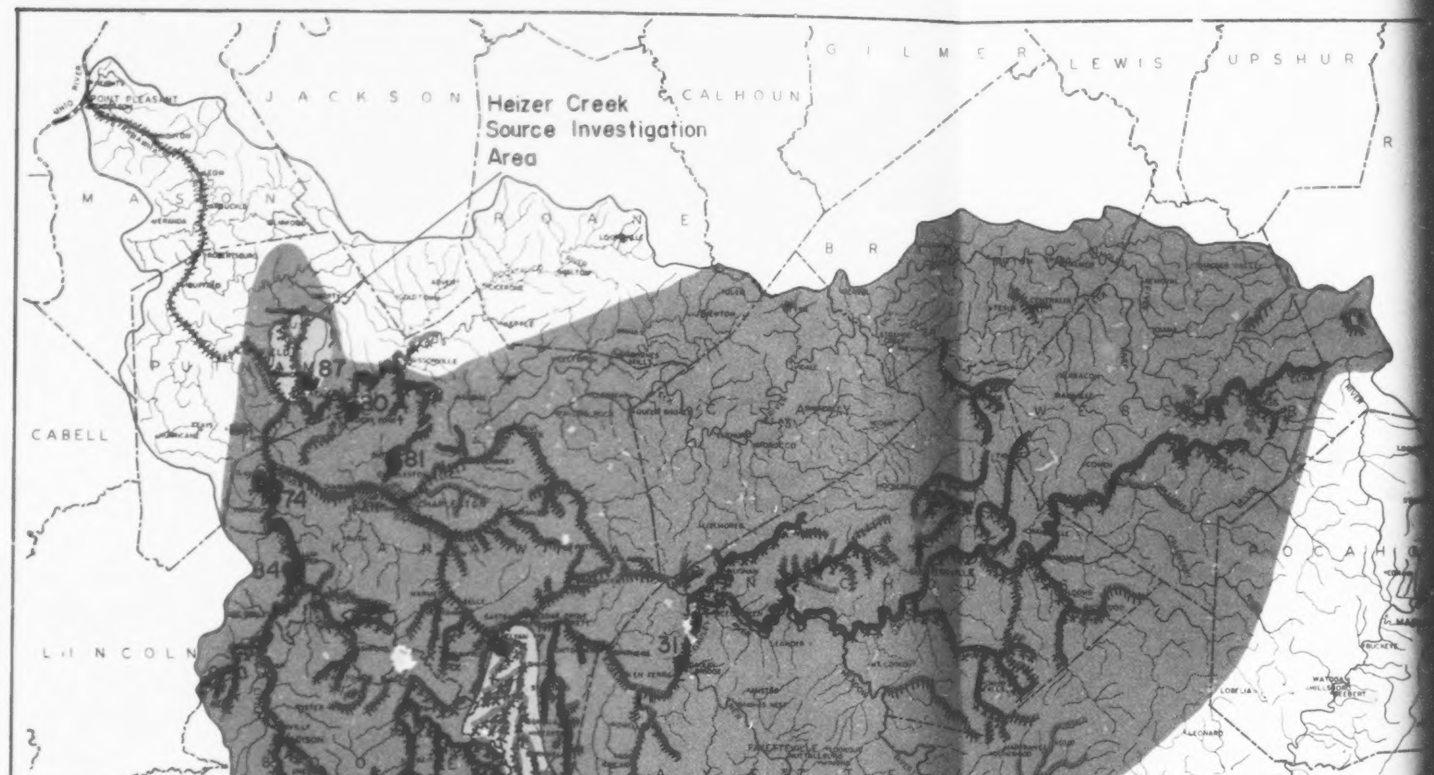
The Coal River (Sta. 74) and its principal tributary, Little Coal River (Sta. 84), receive mine drainage in their headwaters and many tributaries to these streams contribute mine drainage to the main stream. The Coal and Little Coal Rivers are intermittently polluted by mine drainage over their lengths. Sulfate concentrations of 250 mg/l are frequently exceeded in the Coal River watershed due to mine drainage.

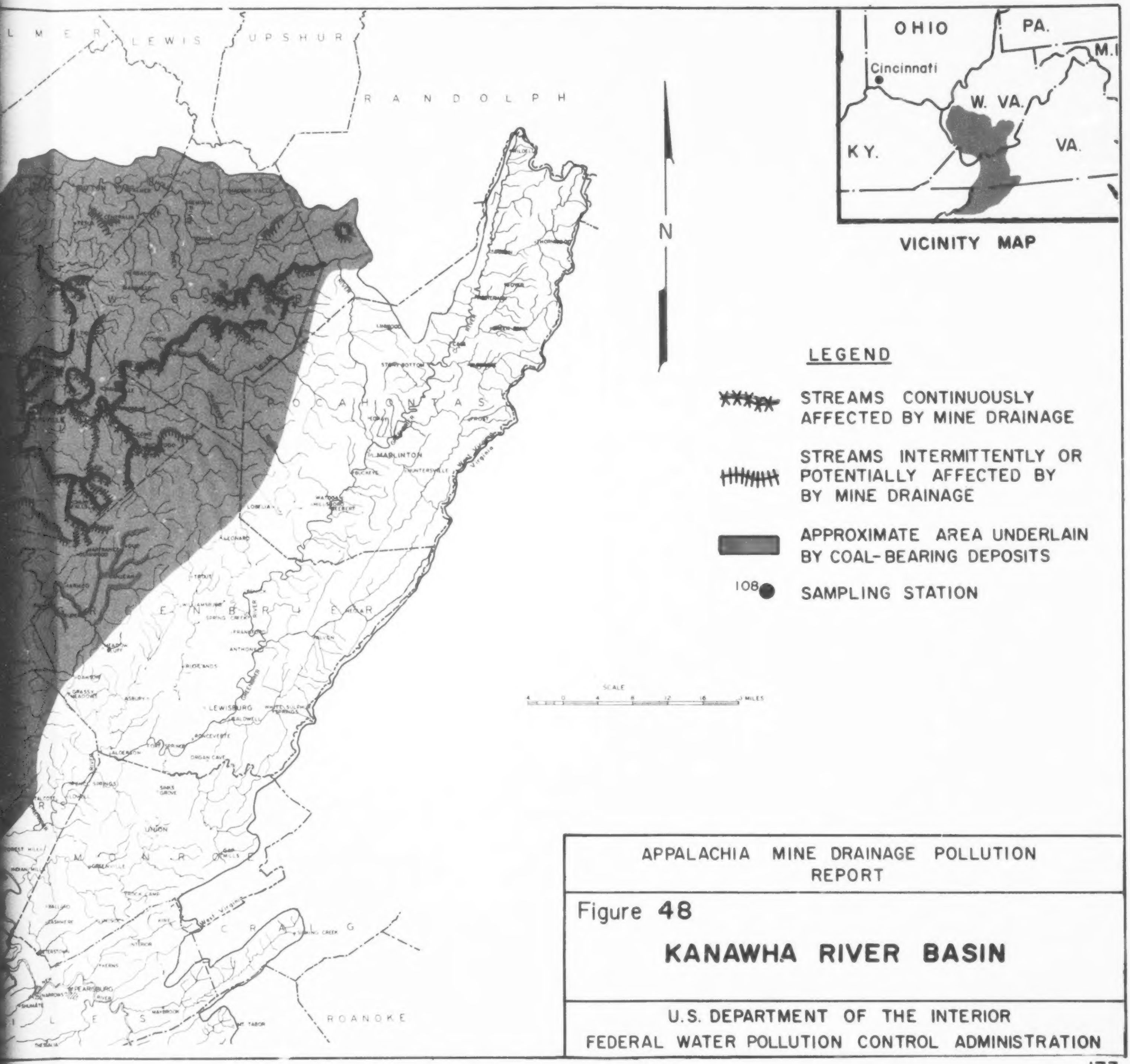
In the Pocatalico River drainage, a number of small tributaries are seriously polluted by mine drainage. A survey of water quality conditions in 1964 showed that over 25 tons of acid per day were being discharged into the Pocatalico River by these tributaries.

In many parts of the Kanawha basin coal mine discharges are alkaline rather than acid. A number of small communities utilize abandoned mines and mine discharges as sources of domestic supply.

Table 16 - Water Quality Data, Kanawha River basin

Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Total Manganese (mg/l)	Total Aluminum (mg/l)	Flow (cfs)
26	Min.		7.9	0.0	97.0	158.0		0.0			13.5
	Max.	16	9.6	1.0	180.0	182.0		0.8			66.0
	Avg.			0.1	131.4	166.0		0.4			41.2
16	Min.		7.7	0.0	37.0	56.0		0.2			5.3
	Max.	16	9.0	2.0	80.0	152.0		0.6			29.5
	Avg.			0.4	59.5	117.8		0.4			13.8
31	Min.		6.7	0.0	55.0	62.0		0.0			1100.0
	Max.	16	9.8	0.0	83.0	68.0		0.4			4300.0
	Avg.			0.0	59.6	66.0		0.2			2762.5
7	Min.		4.9	6.0	1.0	532.0		0.1			1.2
	Max.	16	6.6	105.0	99.0	564.0		900.0			15.4
	Avg.			56.6	13.3	551.5		57.3			7.3
81	Max.	1	5.7	116.0	10.0			0.2			0.1
84	Max.	1	7.7	0.0	43.0			0.2			40.0
74	Max.	1	7.9	0.0	48.0	202.0		0.4			67.0
87	Min.		7.8	0.0	75.0	136.0		0.5			0.5
	Max.	7	8.5	0.0	99.0	248.0		1.2			1.5
	Avg.			0.0	86.0	176.6		0.9			0.8
80	Min.										
	Max.	1	3.8	950.0	0.0	1440.0	3590.0	75.0			0.4
	Avg.										


Heizer Creek Source Investigation Area
Cabin Creek Source Investigation Area
JACKSON
CALHOUN
GILMER
LEWIS
UPSHUR
MASON
ROANE
CABELL
PUTNAM
LINCOLN
LOGAN
WYOMING
McDOWELL
MERCER
SUMMERS
MONROE
GREENBRIER
GILES
CRAIG
ROANOKE
POINT PLEASANT
FAYETTEVILLE
LEWISBURG
PRINCETON
PEARISBURG
BLUEFIELD
West Virginia
Virginia
87
80
81
74
84
31
16
26


LEWIS
UPSHUR
RANDOLPH
WEBSTER
POCAHONTAS
GREENBRIER
MONROE
CRAIG
ROANOKE
GILES
MARLINTON
LEWISBURG
WHITE SULPHUR SPRINGS
RONCEVERTE
ALDERSON
UNION
PEARISBURG
N
SCALE
MILES
OHIO
PA.
Cincinnati
W. VA.
KY.
VA.
VICINITY MAP
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
108
SAMPLING STATION

APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 48

KANAWHA RIVER BASIN

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

B

Scioto River Basin

Description

The Scioto River basin lies in central Ohio, its eastern limits nearly coinciding with the north-south center line of the State, and it forms the principal drainage system of central and southern Ohio. The total drainage area of the basin is 6,510 square miles, comprising about 16 percent of the land area of the State and covering part or all of 31 counties. The portions of eight counties that make up the lower Scioto basin, about one-third of the watershed, are contained in Appalachia.

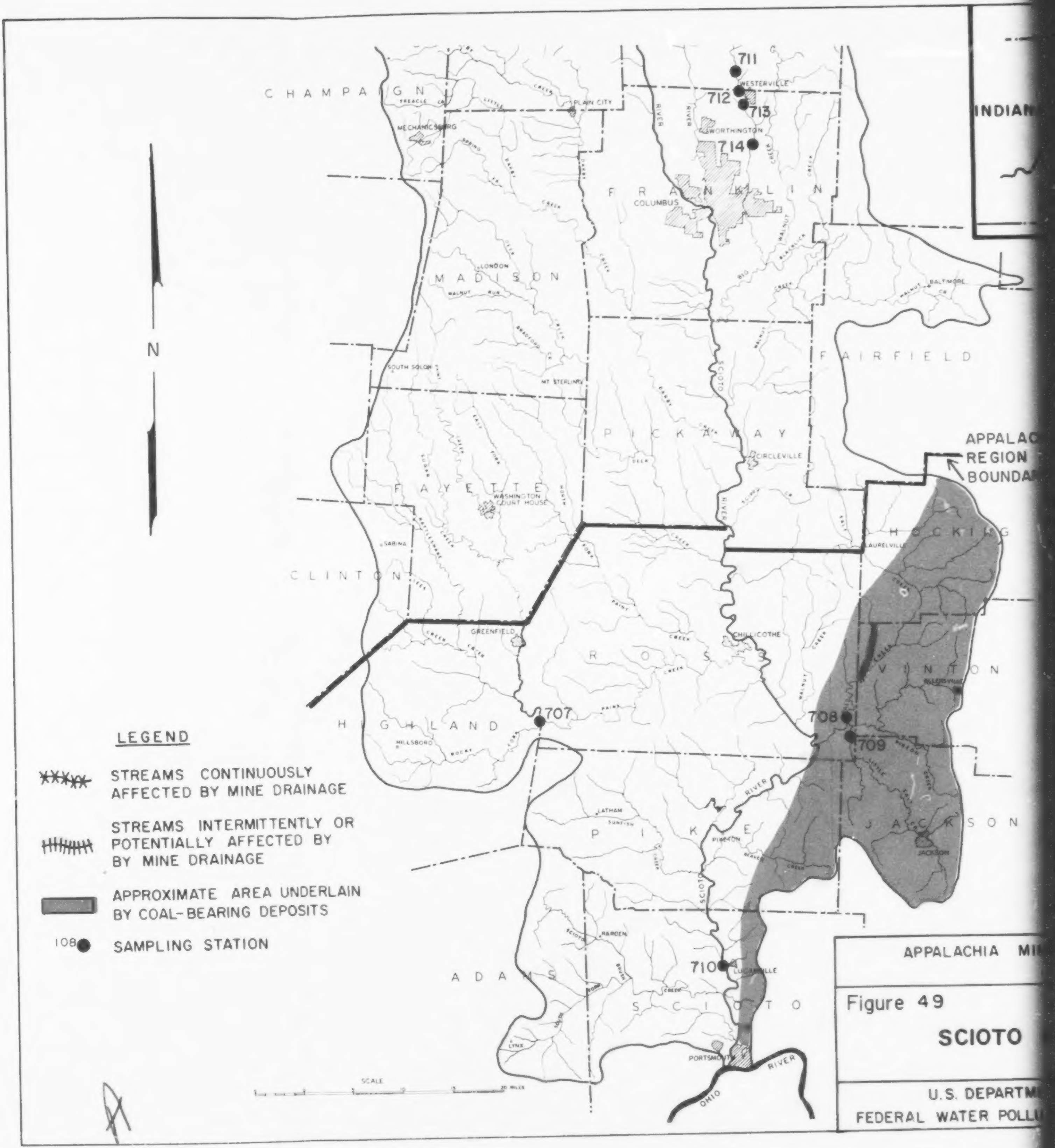
A small recoverable coal reserve of about 150 million tons is estimated for the Scioto basin. The Vinton and Jackson County portions of the watershed contain most of the reserve. Reported coal production is negligible and is limited to Jackson, Vinton, and Hocking Counties.

Mine Drainage Sources and Their Effect on Stream Quality

It is estimated that there are perhaps 200 significant pollution sources originating from inactive mines in the Scioto River basin. There are 1,000 acres of unreclaimed surface-mined land.

Significant stream pollution by coal mine drainage is limited to about 8 miles of streams in two small tributaries to Salt Creek in Vinton County (Fig. 49). About 5 tons/day of acidity is discharged to these streams.

Preceding page blank


CHAMPAIGN
MADISON
FAYETTE
CLINTON
HIGHLAND
ADAMS
FRANKLIN
PICKAWAY
FAIRFIELD
HOCKING
ROSS
VINTON
PIKE
JACKSON
SCIOTO
INDIAN
N
Plain City
Mechanicsburg
Westerville
Worthington
Columbus
London
South Solon
Mt. Sterling
Washington Court House
Sabina
Circleville
Laurelville
Chillicothe
Greenfield
Hillsboro
Latham
Piketon
Jackson
Barden
Lucasville
Lynx
Portsmouth
Scioto River
Ohio River
711
712
713
714
707
708
709
710
APPALAC
REGION
BOUNDAR
SCALE
20 MILES
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
108● SAMPLING STATION

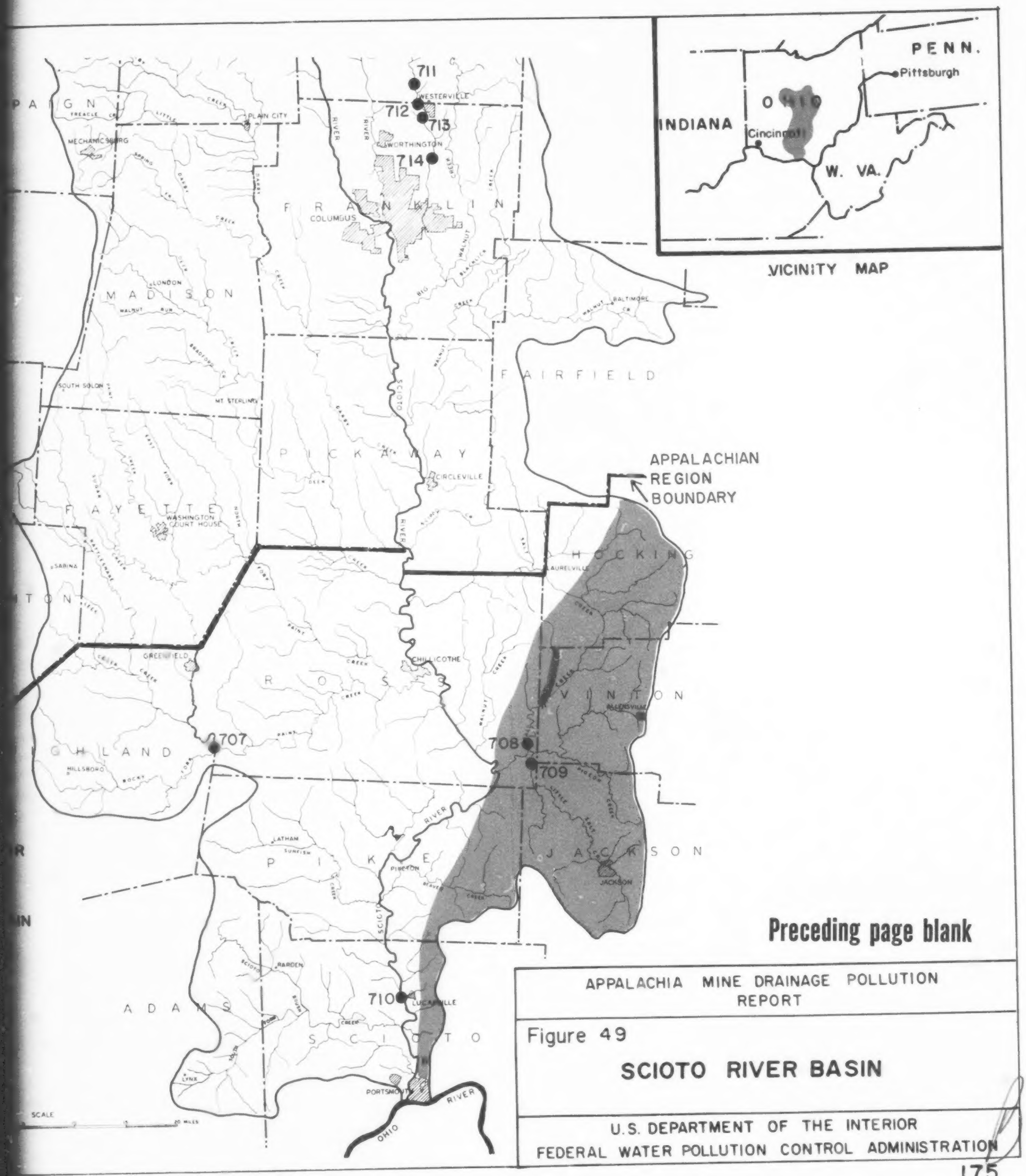
APPALACHIA MI

Figure 49

SCIOTO

U.S. DEPARTM

FEDERAL WATER POLLU


VICINITY MAP
PENN.
Pittsburgh
OHIO
INDIANA
Cincinnati
W. VA.
711
712
713
714
WESTERVILLE
WORTHINGTON
FRANKLIN
COLUMBUS
PLAIN CITY
MECHANICSBURG
MADISON
LONDON
SOUTH SOLON
MT. STERLING
FAIRFIELD
BALTIMORE
PICKAWAY
CIRCLEVILLE
FAYETTE
WASHINGTON COURT HOUSE
SABINA
HOCKING
LAURELVILLE
APPALACHIAN REGION BOUNDARY
ROSS
CHILLICOTHE
GREENFIELD
VINTON
ALLENSVILLE
707
708
709
HIGHLAND
HILLSBORO
PIKE
PIKETON
JACKSON
SCIOTO RIVER
ADAMS
SCIOTO
RARDEN
LYNX
710
LUCASVILLE
PORTSMOUTH
OHIO RIVER
SCALE
20 MILES

Preceding page blank

APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 49

SCIOTO RIVER BASIN

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

Guyandotte River Basin

Description

The Guyandotte River drains 1,670 square miles of southwestern West Virginia, about seven percent of the state (Fig. 50). It is bounded on the west by the Big Sandy River basin and on the east by the Kanawha River basin. Eight counties lie wholly or partly in the basin. All of the Guyandotte River basin is contained in the Appalachian Region. The Guyandotte River has its source near Rhodell, West Virginia, in southern Raleigh County at the confluence of Winding Gulf and Stone Coal Creeks. It flows in a westerly direction for approximately 50 miles, then north for 115 miles to Huntington, where it discharges into the Ohio River, 305 miles below Pittsburgh, Pennsylvania. The only major tributary is the Mud River. Many small upper basin tributaries drain the important coal mining areas in Logan and Wyoming Counties and part of Raleigh County.

The topography of the basin is mountainous and consists of a maze of hills and valleys. Elevations range from under 1,000 feet to between 2,000 and 3,000 feet in the middle and upper portions of the basin. The gradient of the upper half of the river is 11 feet per mile, but in the lower 71 miles the gradient is only 1.8 feet per mile.

Recoverable coal reserves underlie almost all of the drainage area. Only portions of Mingo and Cabell Counties are devoid of mineable coal reserves. The recoverable coal reserve of the Guyandotte River basin is estimated at about five billion tons. The production of coal has been the dominant industry in this area for a long time and should continue to be in view of the remaining coal reserve.

Over the period of record, 1883-1965, over two billion tons of coal were produced from the basin. More than 30 million tons were produced in the basin in 1965. The principal producing counties were Logan, Wyoming, Lincoln and Raleigh (West Virginia Department of Mines, 1965). Logan County has the largest cumulative production figure, 885 million tons. Cabell County has no recorded coal production.

Mine Drainage Sources and Their Effect on Stream Quality

About 200 tons/day of mine drainage acidity are estimated to be formed in the Guyandotte basin, about half of which enters streams unneutralized. A portion of this drainage originates in the 11,000 acres of unreclaimed surface-mined land in the basin.

Preceding page blank

Coal mining is the major industry in the upper half of the Guyandotte basin and a large number of streams there are affected by this activity (Fig. 50). Serious water quality problems are commonly caused by silt and fine coal particles emanating from coal mining and preparation sites. The Raleigh and Wyoming County portions of the basin are particularly affected in terms of numbers of streams and total miles of streams degraded.

A total of 288 miles of streams in the Guyandotte basin are considered to be continuously polluted, including the total length of the Guyandotte River (164 miles) and 124 miles of tributary streams. Eleven miles of tributary streams are intermittently polluted.

The Guyandotte receives mine drainage in its upper portion from Stone Coal Creek, Devils Fork, Allen Creek, Slab Fork, and Barkers Creek (Sta. 178). The Guyandotte River at Tralee, West Virginia (Sta.190), below the affected tributaries mentioned, contained acidity in excess of alkalinity on one occasion during the stream survey. The stream pH did not fall under 6.8 but total mineralization, hardness, sulfate, iron, and manganese were high as a result of the upstream mine drainage influence.

Downstream from Tralee the Guyandotte River receives small amounts of mine drainage from tributaries in Wyoming County above Clear Fork, principally Pinnacle and Indian Creeks.

The Clear Fork was the largest contributor of acidity to the Guyandotte River during the 1966 survey. Virtually the entire Clear Fork watershed is polluted. Laurel Fork of Clear Fork near Jesse, West Virginia (Sta. 179) carried a net acidity load of 12 tons/day and had a minimum pH of 5.4. Clear Fork at Toney Fork, West Virginia (Sta. 180) had a pH range of 3.5 to 5.7 and carried a net acidity load of 37 tons/day.

Little Huff Creek, which enters the main stream at the Wyoming County line (Sta. 184) discharged an average acid load of 5 tons/day during the study period.

Little additional mine drainage enters the Guyandotte in the Logan County reach of the stream. Island Creek is the principal affected stream in this section. Island Creek was an alkaline stream when studied but had high concentrations of hardness, sulfate, iron, and manganese (Sta. 187).

The Guyandotte River near Logan, West Virginia (Sta. 198) was an alkaline stream and had assimilated the acid loads received over the Wyoming County reach of the drainage area. Residual effects of mine drainage were reflected at this location in high concentrations of other related constituents.

The Guyandotte River at Branchland, West Virginia (Sta. 189) is generally an alkaline stream, but as at Logan it had high hardness, sulfate, and metal concentrations. Near its mouth, the Guyandotte was alkaline, but carried high concentrations of mine drainage-related constituents (Sta. 197).

One of the major water quality problems in the Guyandotte basin is the intermittent occurrence of fine coal and silt in the streams. These materials are washed from mining areas during periods of precipitation, or, are allowed to escape from mining and preparation facilities.

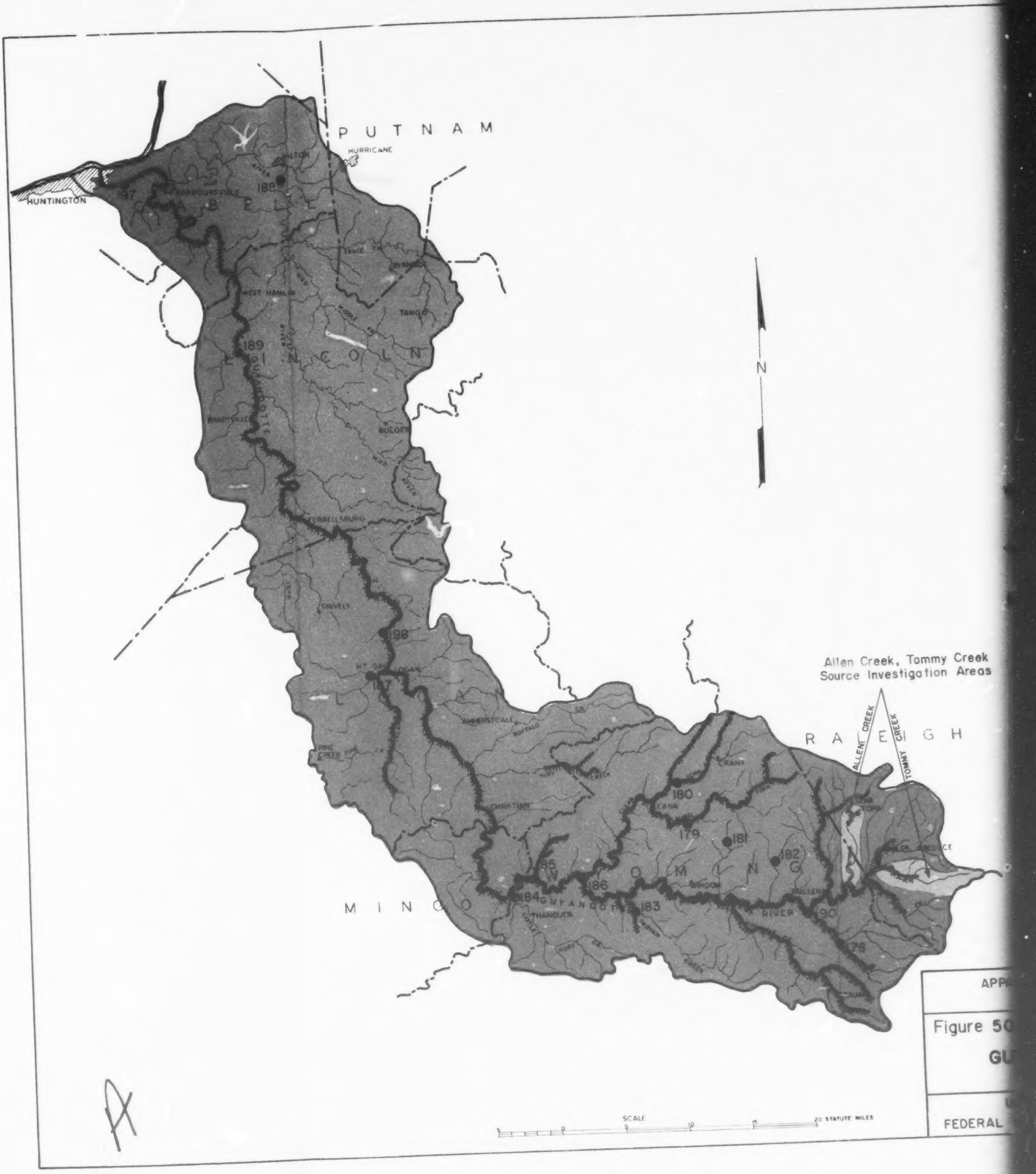
Table 17 - Water Quality Data, Guyandotte River basin

Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Total Manganese (mg/l)	Total Aluminum (mg/l)	Flow (cfs)
178	Min.		6.7	0.0	12.0	23.0	35.0	0.0	0.0	0.8	0.4
	Max.	6	7.7	61.0	119.0	110.0	66.0	8.4	2.1	8.5	76.5
	Avg.			17.0	34.0	55.5	46.5	1.8	0.6	2.5	18.0
179	Min.		5.4	5.0	2.0	45.0	40.0	0.6	0.5	1.1	2.0
	Max.	6	7.1	115.0	54.0	109.0	130.0	12.0	2.4	5.0	500.0
	Avg.			38.0	26.7	73.8	81.2	3.2	0.9	2.6	145.2
180	Min.		3.5	58.0	0.0	162.0	165.0	0.0	2.0	7.5	0.6
	Max.	6	5.7	608.0	13.0	340.0	690.0	216.0	58.6	260.0	180.0
	Avg.			274.8	3.8	251.2(5)*	348.3	42.4	13.7	59.7	63.9
181	Min.		3.8	5.0	0.0	14.0	20.0	0.2	0.0	0.3	0.4
	Max.	6	6.5	25.0	17.0	70.0	23.0	0.6	0.3	0.6	12.0
	Avg.			16.3	9.8	32.5	20.8	0.4	0.2	0.5	3.2
182	Min.		6.1	3.0	10.0	15.0	14.0	0.6	0.2	0.7	1.0
	Max.	4	7.3	24.0	18.0	58.0	23.0	4.2	0.8	5.9	28.9
	Avg.			12.5	13.3	33.3	19.3	1.9	0.4	2.8	10.9
183	Min.		6.7	0.0	8.0	24.0	3.0	0.5	0.1	0.6	0.4
	Max.	6	7.2	115.0	74.0	57.0	25.0	1.2	0.4	4.2	220.0
	Avg.			31.2	40.8	40.5	15.3	0.8	0.2	2.0	61.3
184	Min.		6.4	12.0	8.0	15.0	30.0	0.6	0.2	0.0	1.0
	Max.	6	7.1	79.0	150.0	115.0	75.0	18.7	3.1	18.7	420.0
	Avg.			40.3	41.2	60.7	55.7	5.1	0.9	5.1	94.4
185	Min.		6.8	0.0	18.0	74.0	75.0	0.0	0.2	0.0	65.0
	Max.	6	7.6	39.0	196.0	162.0	238.0	6.2	3.4	4.0	4120.0
	Avg.			15.7	86.0	101.2	121.3	2.5	1.0	1.5	986.2

Preceding page blank

Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Total Manganese (mg/1)	Total Aluminum (mg/1)	Flow (cfs)
186	Min.		5.1	7.0	1.0	26.0	65.0	0.0	0.7	1.8	1.0
	Max.	6	6.5	316.0	15.0	297.0	425.0	94.0	14.0	13.0	460.0
	Avg.			82.0	5.8	148.2	216.7	17.6	4.4	6.1	131.0
187	Min.		6.7	0.0	90.0	135.0	225.0	3.1	0.3	0.0	20.0
	Max.	6	7.6	28.0	334.0	300.0	625.0	8.8	0.7	8.1	80.0
	Avg.			12.2	250.3	214.2	445.8	5.6	0.5	3.3	36.4
188	Min.		6.4	0.0	7.0	35.0	2.0	0.1	0.0	0.1	1.0
	Max.	6	8.0	20.0	48.0	82.0	30.0	5.9	3.4	2.1	975.0
	Avg.			9.3	36.8	56.5	17.5	1.8(5)	1.2	1.1(5)	183.0
189	Min.		6.7	0.0	22.0	95.0	90.0	0.3	0.0	1.9	83.0
	Max.	6	7.3	27.0	121.0	248.0	400.0	8.4	0.7	6.2	2855.0
	Avg.			7.0	78.5	166.5	212.5	2.4	0.4	3.1	661.0
190	Min.		6.8	0.0	26.0	73.0	53.0	1.1	0.1	1.1	26.5
	Max.	6	7.9	28.0	199.0	170.0	260.0	3.4	1.6	3.6	900.0
	Avg.			9.5	136.5	125.2	179.7	1.9	0.7	2.3	200.3
197	Min.		6.6	0.0	38.0	100.0	110.0	0.2	0.1	0.4	140.0
	Max.	6	7.5	28.0	100.0	198.0	340.0	4.9	1.1	4.7	6000.0
	Avg.			8.7	67.7	141.0	195.8	2.5	0.5	3.2	1346.7
198	Min.		6.9	0.0	22.0	70.0	85.0	0.4	0.1	0.9	65.0
	Max.	6	7.4	26.0	155.0	230.0	345.0	3.8	0.8	8.2	250.0
	Avg.			9.8	86.0	168.3	210.8	1.7	0.4	4.2	105.0

*(5) Indicates the number of samples used in averages when other than the maximum.


PUTNAM
HURRICANE
HUNTINGTON
197
BARBOURSVILLE
MILTON
188
CABELL
TRACE CR.
BRANCHLAND
WEST HAMLIN
MUD
MIDDLE FK.
TANGO
189
LINCOLN
GUYANDOTTE
MUD RIVER
BULGER
FERRELLSBURG
SNIVELY
198
MT. GAY
LOGAN
187
AMHERSTDALE
BUFFALO CR.
PINE CREEK
CHRISTIAN
HUFF CREEK
180
CRANY
179
181
182
185
WYOMING
186
184
GUYANDOTTE RIVER
183
HANOVER
INDIAN CREEK
HUFF CR.
MULLENS
190
178
MINGO
RALEIGH
ALLEN CREEK
TOMMY CREEK
Allen Creek, Tommy Creek
Source Investigation Areas
N
SCALE
5 0 5 10 15 20 STATUTE MILES

APP

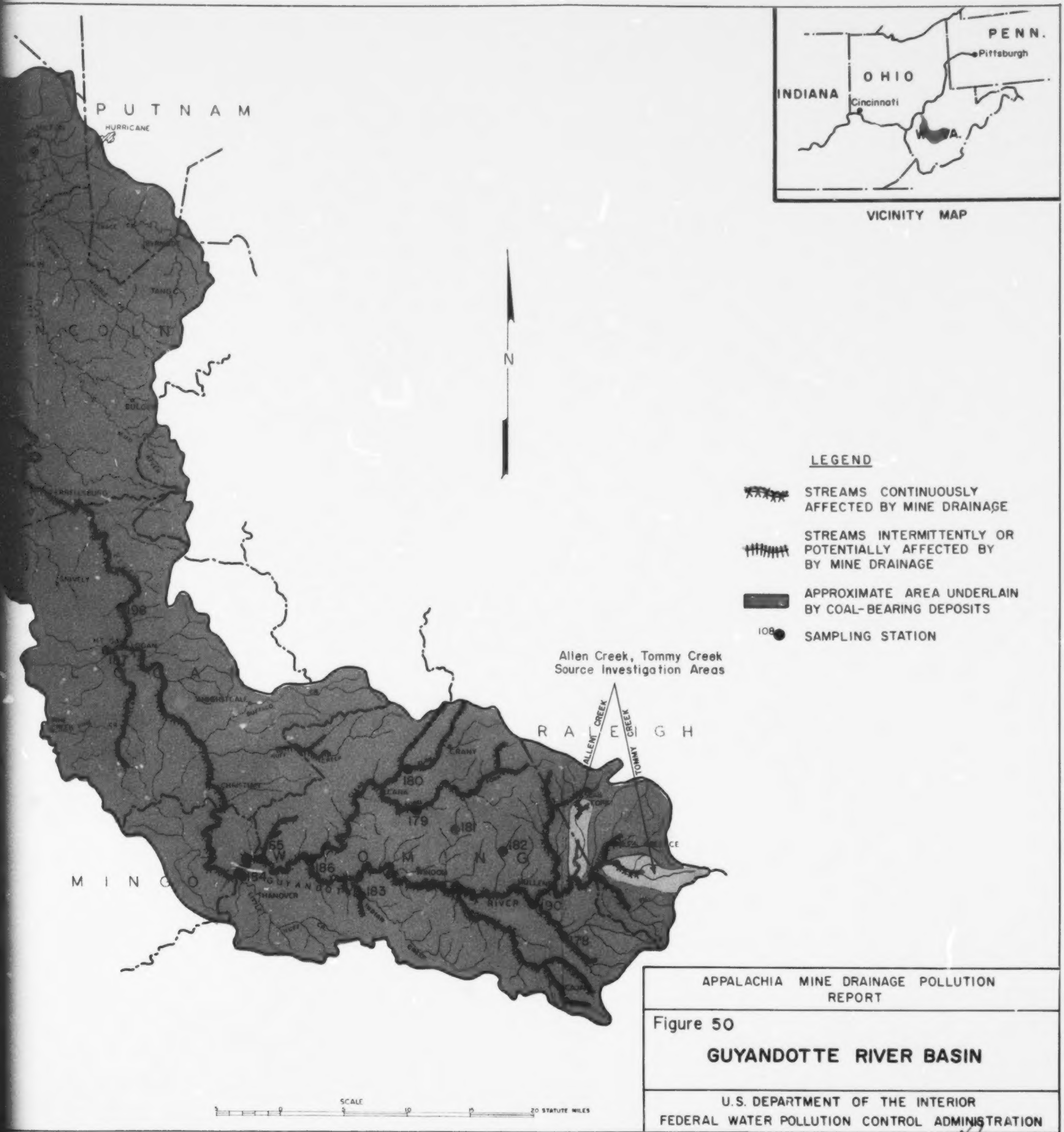
Figure 50

GU

U

FEDERAL

A


PENN.
Pittsburgh
OHIO
INDIANA
Cincinnati
W. VA.
VICINITY MAP
N
P U T N A M
HURRICANE
L I N C O L N
L O G A N
R A L E I G H
M I N G O
W Y O M I N G
GUYANDOTTE RIVER
198
187
180
179
181
182
155
184
186
183
190
178
Allen Creek, Tommy Creek
Source Investigation Areas
ALLEN CREEK
TOMMY CREEK
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
108 SAMPLING STATION
SCALE
5 0 5 10 15 20 STATUTE MILES

APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 50

GUYANDOTTE RIVER BASIN

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

B

Big Sandy River Basin

Description

The Big Sandy River is formed by the junction of Tug and Levisa Forks at Louisa, Kentucky, and flows northerly 27 miles to enter the Ohio River about 10 miles downstream from Huntington, West Virginia. It drains 4,280 square miles, of which 2,330 are drained by Levisa Fork and 1,550 by Tug Fork (Fig. 51). Principal tributaries to Levisa Fork of the Big Sandy River are Russell Fork, Beaver Creek, and Johns Creek. The basin is bounded by the Guyandotte River basin on the east, the Tennessee River basin on the south and the Kentucky and Licking River basins on the west. All of the Big Sandy River basin is within the Appalachian Region.

The basin varies from mountainous terrain in its upper portions to hilly areas along the Big Sandy River. Some of the most rugged portions of the three states is found in the headwaters of the Tug and Levisa Forks of the Big Sandy River.

Coal production is the major industry in the basin and there are more than 2,800 active mines, the majority of which are underground. Bituminous coal reserves are present in 16 of the counties that are either wholly or partly within the basin. In 1963 the total recoverable coal reserves were estimated to be more than 11 billion tons. Coal has been mined in most of the counties, and in 1965 production was more than 65 million tons. The major producing counties were Pike and Floyd Counties in Kentucky; Buchanan, Dickinson, and Wise Counties in Virginia; and McDowell and Mingo Counties in West Virginia.

Mine Drainage Sources and Their Effect on Stream Quality

Sulfate loadings in the Big Sandy at Cattletsburg (Ceredo) for the years 1957-1959 and 1962-1963 averaged 800 tons/day (Fig. 52), of which 620 tons/day is considered to have originated from mine drainage acidity. About 300 tons/day of unneutralized acidity is estimated to reach streams in the basin.

Approximately 500 miles of streams in the Big Sandy basin are polluted by coal mine drainage and activities related to coal mining as shown in Table 18. Part of the pollutants in these streams originate in the 31,000 acres of unreclaimed strip-mined land in the basin. It is not known how many individual pollution sources may exist. Thirty potential pollution sites were examined in the Dismal Fork area (Fig. 51), but only two of the thirty had drainage.

Preceding page blank

Table 18 - Lengths of Streams Polluted by Mine Drainage
Big Sandy River Basin

Stream	Drainage Area (square miles)	Continuously Polluted (miles)		Intermittently Polluted (miles)		Total (miles)
Big Sandy River	4,294			27		27
Tributaries to Big Sandy				2		2
Tug Fork				70		70
Tributaries		58		74		132
Levisa Fork				131		131
Tributaries				138		138
		58	+	442	=	500

Tributary streams of the basin in which mine drainage pollution effects have been observed to be the most serious are those in the headwaters in McDowell and Mingo Counties, West Virginia, Buchanan and Dickinson Counties, Virginia; and Pike and Floyd Counties, Kentucky. The streams in these locations drain the areas of heaviest mining activity in the basin.

Generally, the streams in the Big Sandy River basin that are affected by mine drainage, although highly mineralized, are not characterized by high acidity concentrations. Fine coal and silt are often present in the streams of the basin due to surface runoff and discharges from coal mining and preparation sites. Concern has been expressed over detrimental effects of coal washery discharges above Fishtrap Reservoir on Levisa Fork near the Kentucky-Virginia line.

Tug Fork of Big Sandy River receives some intermittent mine drainage directly in its reach above Welch, West Virginia and from the Elkhorn Creek, Dry Fork, and Panther Creek watersheds (Sta. 192) in McDowell County, West Virginia. Tug Fork near Taeger, West Virginia (Sta. 194) reflected the mine drainage influence in total mineralization, and high sulfate, iron, and manganese concentrations.

In the Mingo County, West Virginia reach of the Tug Fork several small tributaries contribute mine drainage to the main stream above Williamson, West Virginia. Below Williamson, Pigeon Creek in West Virginia and Big and Wolf Creeks in Kentucky are affected. Pigeon Creek (Sta. 196) had a minimum pH of 6.4 during the survey. It contained high hardness, sulfate, iron, and manganese concentrations on occasion and had acidity in excess of alkalinity on one occasion.

Tug Fork below Pigeon Creek, near Kermit, West Virginia (Sta. 195) had a minimum pH of 5.9, acidity in excess of alkalinity on one occasion, and high concentrations of sulfate, iron, and manganese during part of the study period.

Like Tug Fork, Levisa Fork is affected in its headwaters area. The pH in the Levisa Fork at the Kentucky-Virginia State line (Sta. 02) did not fall below 6.7 but the river contained high concentrations of mine drainage-related constituents. Russell Fork (Sta. 03) contributed an average net acid load of 20 tons/day. The pH of this stream did not fall below 6.2. Levisa Fork below Pikeville (Sta. 09) contained high residual concentrations of sulfate, iron, and manganese from mine drainage received in its upper reaches.

Below Pikeville there are a number of tributaries to Levisa Fork that intermittently contribute additional quantities of mine drainage in Floyd and Johnson Counties, Kentucky. Beaver, Middle, Johns, Toms, and Greasy Creeks in these counties are intermittently polluted by mine drainage.

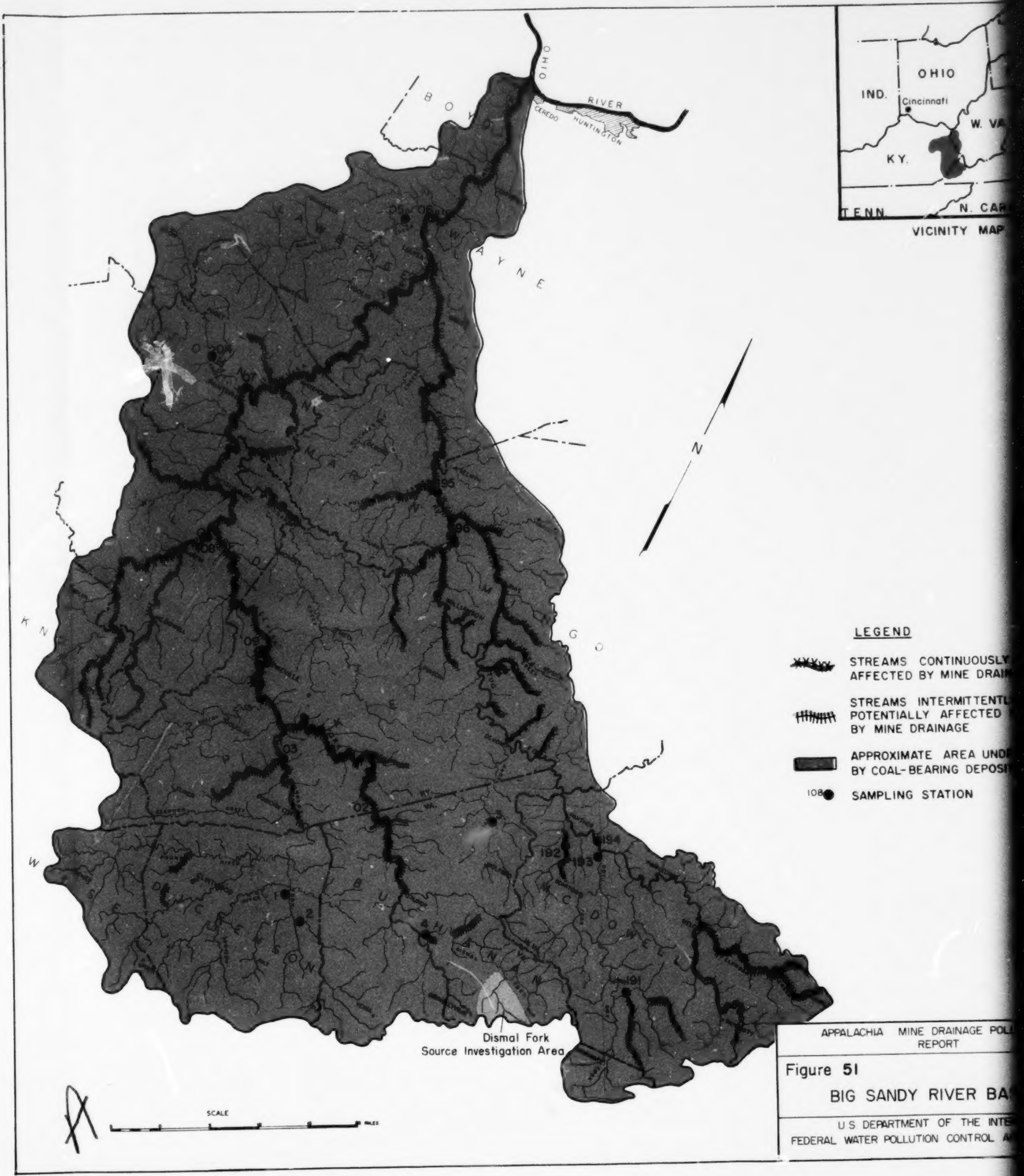
The Big Sandy River at Louisa, Kentucky (Sta. 06) contained acidity in excess of alkalinity during part of the survey period and had a hardness range of 60 to 582 mg/l. Sulfate, iron, and manganese concentrations were 52 to 320 mg/l, 1.0 to 25.0 mg/l, and 0.1 to 1.3 mg/l, respectively.

Table 19 - Water quality data, Big Sandy River basin

Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Total Manganese (mg/l)	Total Aluminum (mg/l)	Flow (cfs)
02	Min.		6.7	0.0	13.0	103.0	80.0	0.6	0.3	1.4	6.7
	Max.	6	7.8	28.0	56.0	348.0	400.0	9.1	1.6	9.9	4300.0
	Avg.			14.0	32.8	251.7	233.3	3.1	0.8	4.0	759.3
03	Min.		6.2	0.0	20.0	18.0	40.0	0.5	0.7	1.3	27.3
	Max.	6	7.9	175.0	55.0	124.0	100.0	115.0	12.4	107.0	3470.0
	Avg.			39.7	36.2	69.0	70.0	22.3	3.1	21.1	1533.1
04	Min.		6.7	0.0	35.0	144.0	15.0	0.0	0.2	0.0	2.0
	Max.	6	7.8	96.0	66.0	656.0	50.0	16.8	1.3	63.8	61.0
	Avg.			21.0	48.7	336.2	29.2	3.3	0.5	11.2	25.7
05	Min.		6.4	13.0	15.0	190.0	12.0	0.0	0.1	0.6	11.0
	Max.	6	7.0	63.0	38.0	920.0	30.0	12.0	2.5	25.2	320.0
	Avg.			30.7	24.5	455.0	23.2	3.1	1.1	7.3	92.6
06	Min.		6.9	2.0	19.0	60.0	52.0	1.0	0.1	1.2	170.0
	Max.	6	7.4	92.0	86.0	582.0	320.0	25.0	1.3	19.1	1680.0
	Avg.			28.3	49.3	190.3	139.5	7.0	0.7	6.1	889.2
07	Min.		6.2	0.0	25.0	58.0	45.0	0.0	0.3	0.0	105.0
	Max.	6	7.4	43.0	48.0	140.0	110.0	15.6	4.6	24.0	11000.0
	Avg.			18.8	33.2	93.0	79.5	6.0	1.4	7.8	3980.5
08	Min.		7.2	0.0	28.0	54.0	85.0	1.0	0.3	0.4	8.1
	Max.	6	7.6	24.0	111.0	186.0	185.0	5.0	1.5	3.4	690.0
	Avg.			13.8	74.0	142.2	135.8	2.8	0.8	1.9	225.6
09	Min.		6.7	0.0	29.0	60.0	40.0	1.2	0.5	2.1	190.0
	Max.	6	7.7	35.0	65.0	152.0	155.0	10.3	2.9	9.8	6900.0
	Avg.			20.5	41.3	105.0	96.3	6.3	1.6	6.4	2341.7

Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Total Manganese (mg/l)	Total Aluminum (mg/l)	Flow (cfs)
1	Min.	6	6.9	0.0	46.0	50.0	36.0	0.4	0.0	0.3	0.5
	Max.		7.8	25.0	125.0	130.0	195.0	3.4	2.4	2.5	228.0
	Avg.			10.3	80.7	80.7	86.7	1.2	0.8	1.2	57.4
2	Min.	6	7.4	0.0	56.0	25.0	40.0	0.1	0.0	0.4	0.4
	Max.		8.4	25.0	167.0	128.0	245.0	1.6	1.3	3.0	98.2
	Avg.			6.5	93.5	77.5	105.2	0.6	0.4	1.4	29.8
3	Min.	6	5.8	0.0	10.0	15.0	35.0	0.5	0.2	0.7	0.3
	Max.		7.2	48.0	87.0	255.0	270.0	16.8	2.9	22.5	1400.0
	Avg.			18.7	46.3	146.0	139.8	3.6	0.8	4.8	265.2
4	Min.	6	5.5	5.0	2.0	107.0	80.0	0.4	0.7	0.0	1.7
	Max.		7.9	59.0	27.0	350.0	415.0	9.1	1.8	9.4	360.0
	Avg.			26.8	17.5	249.8	240.8	2.8	1.3	3.2	73.7
191	Min.	6	6.6	5.0	9.0	37.0	40.0	0.3	0.2	0.1	0.2
	Max.		7.2	50.0	60.0	273.0	300.0	21.6	3.3	17.2	1100.0
	Avg.			25.7	33.0	139.2	138.8	4.5	1.2	4.3	193.7
192	Min.	6	6.6	4.0	12.0	13.0	25.0	0.3	0.2	0.4	1.0
	Max.		7.3	46.0	46.0	67.0	86.0	6.0	1.1	4.0	1630.0
	Avg.			25.7	29.0	46.2	51.5	2.3	0.6	1.8	292.8
193	Min.	6	6.4	0.0	47.0	38.0	45.0	0.0	0.1	0.0	18.6
	Max.		8.6	31.0	326.0	110.0	130.0	13.4	2.9	17.5	880.0
	Avg.			8.0	194.2	87.7	80.8	3.2	0.7	4.8	230.1
194	Min.	6	6.8	0.0	52.0	67.0	50.0	0.0	0.1	0.0	63.0
	Max.		8.1	57.0	299.0	188.0	220.0	14.3	2.8	14.9	2879.0
	Avg.			20.2	193.3	118.8	133.2	3.9	0.8	6.0	784.3

Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Total Manganese (mg/l)	Total Aluminum (mg/l)	Flow (cfs)
195	Min.		5.9	0.0	18.0	46.0	55.0	0.0	0.2	1.4	146.0
	Max.	5	8.2	80.0	148.0	202.0	255.0	5.1	1.0	4.0	5232.0
	Avg.			22.8	71.0	115.6	111.0	2.4	0.6	2.8	2150.2
196	Min.		6.4	0.0	12.0	70.0	60.0	0.0	0.0	0.0	6.0
	Max.	6	7.2	43.0	74.0	348.0	610.0	2.8	1.2	2.8	1400.0
	Avg.			10.0	30.8	151.7	187.8	1.6	0.4	1.7	398.3

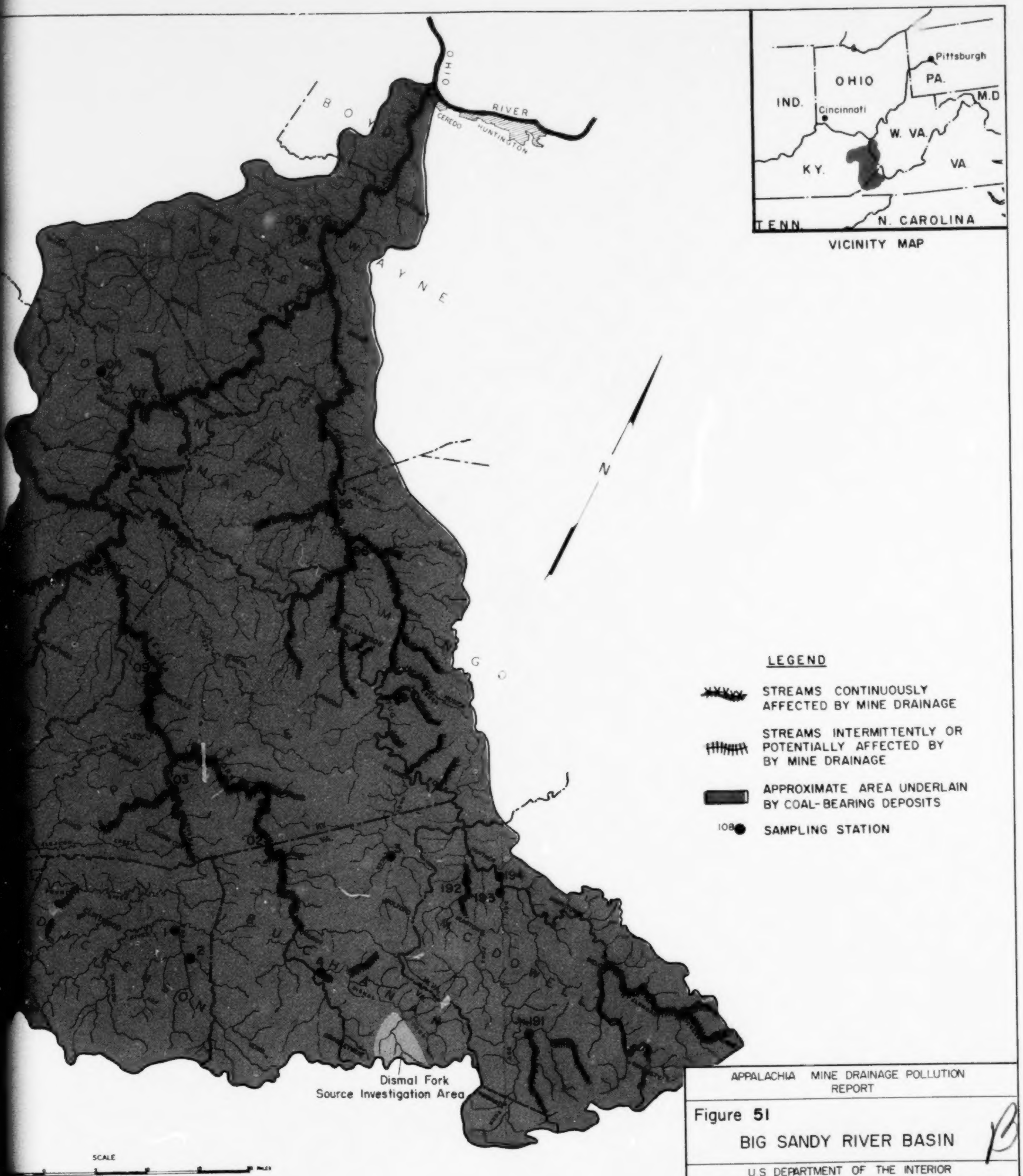

OHIO
IND.
Cincinnati
W. VA
KY.
TENN.
N. CAR
VICINITY MAP
OHIO
RIVER
CEREDO
HUNTINGTON
B O Y D
W A Y N E
M I N G O
K N
W I S E
D I C K E N S O N
B U C H A N A N
M c D O W E
N
105
106
104
107
95
96
108
03
02
192
193
194
1
2
4
191
Dismal Fork
Source Investigation Area
SCALE
MILES
LEGEND
STREAMS CONTINUOUSLY
AFFECTED BY MINE DRAI
STREAMS INTERMITTENTL
POTENTIALLY AFFECTED
BY MINE DRAINAGE
APPROXIMATE AREA UND
BY COAL-BEARING DEPOSI
108
SAMPLING STATION

APPALACHIA MINE DRAINAGE POL
REPORT

Figure 51

BIG SANDY RIVER BA

U.S DEPARTMENT OF THE INTE
FEDERAL WATER POLLUTION CONTROL A


OHIO RIVER
CEREDO
HUNTINGTON
BOYD
WAYNE
MINGO
N
195
196
192
193
194
191
02
03
Dismal Fork
Source Investigation Area
SCALE
MILES
OHIO
IND.
Cincinnati
Pittsburgh
PA.
MD
W. VA.
KY.
VA
TENN.
N. CAROLINA
VICINITY MAP
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
108 ● SAMPLING STATION

APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 51

BIG SANDY RIVER BASIN

B

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

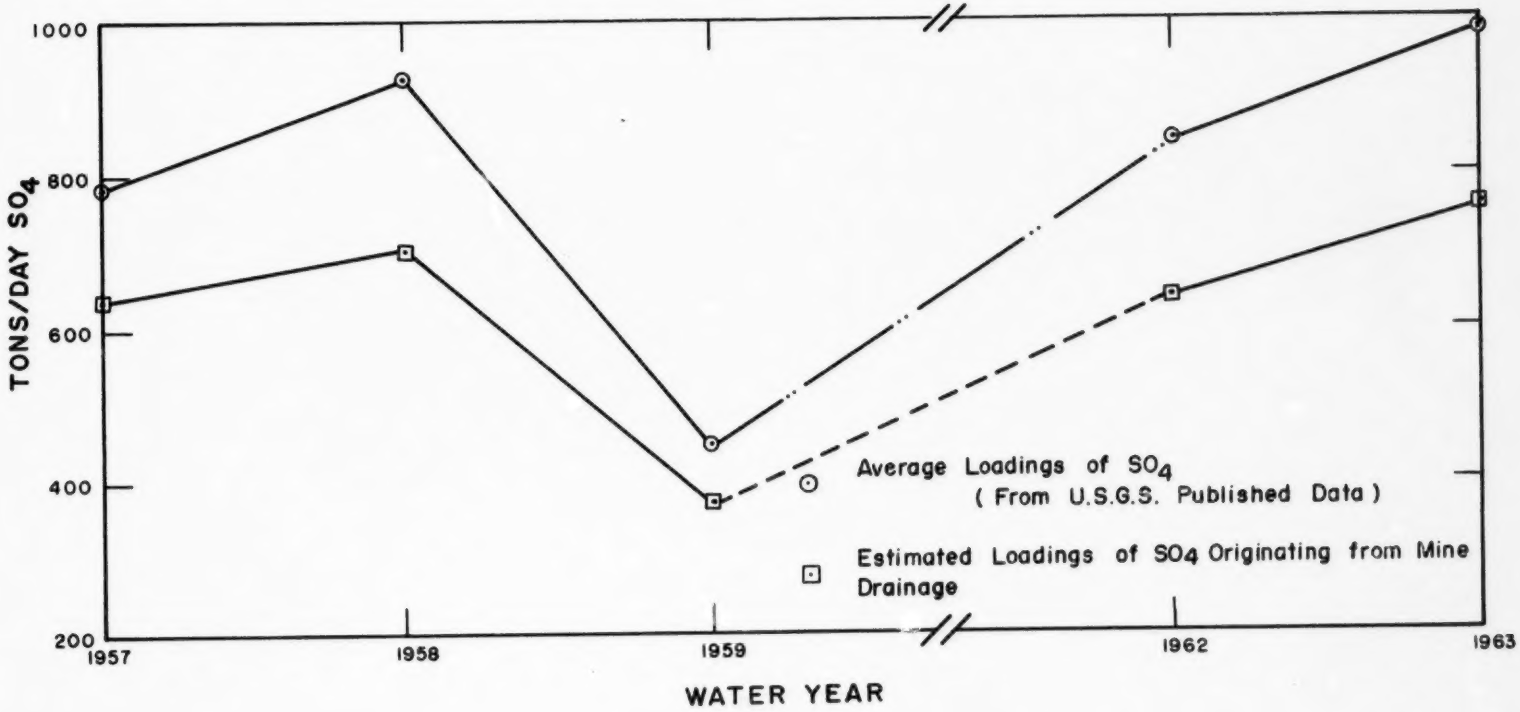


Figure 52. Average loads of total sulfate and sulfate considered to originate from coal mine drainage carried by the Big Sandy River at Catlettsburg, Kentucky.

Ohio River Main Stem and Minor Tributaries

Description

Areas along both banks of the Ohio River main stem from Pittsburgh, Pennsylvania to Meldahl Dam on the Ohio near Foster, Kentucky, draining directly to the river, are included in this section of the study. The sum of the minor tributary drainage areas along this 438 mile stretch of the Ohio River is about 14,000 square miles. The largest of the tributaries in this area so defined are Little Beaver Creek (Ohio-Pennsylvania); Middle Island Creek (West Virginia); Raccoon Creek (Ohio); Twelvepole Creek (West Virginia); Little Muskingum River (Ohio); and Ohio Brush Creek (Ohio). With the exception of Columbiana and Mahoning Counties (Ohio) in the Pittsburgh to New Cumberland Dam reach of the Ohio River, and Bracken and Mason Counties, Kentucky, in the Belleville to Meldahl Dam reach, the entire drainage area is contained in the Appalachian Region.

The valley of the Ohio River gradually widens downstream. At Point Pleasant, West Virginia, the valley contains alluvial deposits about two and one-half miles wide and in some places these deposits are over 100 feet thick. The Ohio Valley is bordered by an almost continuous band of rough unglaciated land from the mountainous headwater regions of western Pennsylvania through the hilly country of southeastern Ohio into the Knobs section of Kentucky. The minor tributary drainage areas are generally hilly and rough.

Approximately 30 million tons of coal were produced in this watershed in 1965. More than one-half of the tonnage was from the State of Ohio, and the total tonnage was about equally divided between surface and underground mining methods. Production in this area will greatly increase in the near future to supply fuel requirements of a number of steam electric generating plants which are proposed to be built along the Ohio River.

Mine Drainage Sources and Their Effect on Stream Quality

Source investigations have been made in four of the minor tributary watersheds along the upper Ohio River as listed below and as shown in Figures 53, 54 and 55. Additional data concerning source type and acid contribution are given in Table 1-A. Inactive surface and underground mines are the principal source of drainage in the Wheeling and Raccoon Creek drainages. Two active surface mines contribute most of the drainage to Captina Creek.

Preceding page blank

Mine Drainage Source Areas Studied
Ohio Main Stem

Watershed	Area (square miles)	Drainages Sampled and Measured
Yellow Creek (Figure 53)	44	4
Wheeling Creek (Figure 55)	49	72
Captina Creek (Figure 55)	180	12
Raccoon Creek (Figure 55)	57	142

A total of 48,000 acres of unreclaimed strip-mined land presently exist in this area. Surface and underground sources are estimated to contribute 1000 tons/day of unneutralized acidity to the upper Ohio River and its minor tributaries.

Over 1,300 miles of minor tributaries to the Ohio River were found to be significantly affected by mine drainage (Table 20). About 90 percent of the affected streams were found to be continuously polluted.

Table 20. Length of Streams Polluted by Mine Drainage
Upper Ohio River Main Stem and Minor Tributaries

Stream	Drainage Area (square miles)	Continuously Polluted (miles)	Intermittently Polluted (miles)	Total (miles)
Pittsburgh to New Cumberland	1,609		24	24
Minor Tributaries		159		159
New Cumberland to Belleville Dam	3933			
Minor Tributaries		365	38	403
Belleville Dam to Meldahl Dam	7,090			
Minor Tributaries		640	104	744
		1,164 +	166 =	1,330

A. Pittsburgh to New Cumberland Dam

The Ohio River in this upper drainage area is affected by mine drainage primarily due to the influence of the Monongahela River. The Ohio River at the Ohio-West Virginia-Pennsylvania state boundary carried an average acidity load of about 350 tons/day over the period 1945 to 1960. The Ohio River is presently considered to be intermittently polluted by mine drainage from its origin to the entry of the Beaver River 25 miles downstream.

In the drainage area of this reach of the Ohio River there are 195 miles of streams polluted by mine drainage. Polluted minor tributaries include Chartiers Creek, Montour Run, Raccoon Creek, Sixmile Run, and Yellow Creek (Fig. 53). Chartiers Creek and its tributary, Robinson Run, and Raccoon Creek are the most seriously affected.

Chartiers Creek was not an acid stream during the 1966 survey, but did contain high hardness, sulfate, iron, and manganese from mine drainage discharged within its drainage area (Sta. 587). The pH of Raccoon Creek ranged from 3.3 to 5.1 during the survey (Sta. 588) and the stream discharged an average load of 25 tons/day acidity to the Ohio. Yellow Creek is affected by mine drainage over most of its length, but is not acid. The pollution is reflected by high levels of mine drainage indicators (Sta. 681).

B. New Cumberland Dam to Belleville Dam

The middle reach of the Ohio drains an area of 3,933 square miles of Ohio, Pennsylvania, and West Virginia. Mine drainage stream pollution in this area is more severe than in the upper drainage area. Some 400 miles of streams are polluted in varying degrees by mine drainage in this watershed (Fig. 54 and Table 20).

Listed in downstream order, tributary basins significantly polluted with mine drainage are: Harmon Creek (West Virginia); Cross, Short, Wheeling, McMahon, Captina, Sunfish and Duck Creeks (Ohio). All these streams exhibit high concentrations of one or more of the constituents prevalent in mine drainage (i.e., hardness, sulfate, iron, and manganese).

During 1966 Harmon Creek (Sta. 174) and McMahon Creek (Sta. 685) were consistently acid and discharged average net acidity loads of 32 tons and 1 ton/day, respectively, to the Ohio River. The other streams sampled generally contained alkalinity in excess of acidity but discharged large iron, manganese, hardness and sulfate loads to the Ohio River.

Tributary watersheds carrying mine drainage in smaller amounts include Aunt Clara, Cross, Buffalo, Short, and Wheeling Creeks in West Virginia and Little Muskingum River in Ohio. Additional drainage enters the Ohio River from active and inactive mine sites located along this reach of the Ohio River valley.

Two fish kills, resulting from acid mine drainage, are reported to have occurred in minor tributaries in this portion of the Ohio River basin during 1966.

C. Ohio River Belleville Dam to Meldahl Dam

The lowermost minor tributary watershed area is more severely polluted than either of the upper tributary watersheds. This section contains more than 700 miles of streams polluted by mine drainage (Fig. 55 and Table 20). The Raccoon Creek basin, which drains 684 square miles of southeastern Ohio contains 230 miles of polluted streams and is the most severely affected tributary watershed in this reach. Nearly all of the affected streams in this area are in Ohio.

Proceeding downstream the tributary basins significantly polluted with mine drainage are: Shade River, Leading Creek, Raccoon Creek, Symmes Creek, and Pine Creek, Ohio. Other affected watersheds include Campaign Creek, Indian Guyan Creek and Little Scioto River in Ohio and Twelvepole Creek in West Virginia.

Shade River (Sta. 687) and Leading Creek (Sta. 688) in Meigs County, Ohio, were sampled during the survey. These streams exhibited minimum pH readings of 4.0 and 6.7 and each discharged an average acid load of 2.5 tons/day. Both streams were acidic through most of the survey.

Raccoon Creek enters the Ohio River near Gallipolis, Ohio, draining some of the oldest and most intensively mined areas of southeastern Ohio. Mining in this watershed began on a large scale in 1856 coincident with railroad construction. Stream surveys by the Ohio River Basin Project of the FWPCA in 1965 and 1966 show that most of the streams in the Raccoon Creek basin are grossly polluted by mine drainage and are acid in character. Acidity concentrations as high as 424 mg/l and pH readings as low as 2.8 were recorded during these studies. Raccoon Creek carried an average net acidity load of 100 tons/day, seven miles below the mouth of Little Raccoon Creek.

Table 21 - Water quality data, main stem Ohio River basin

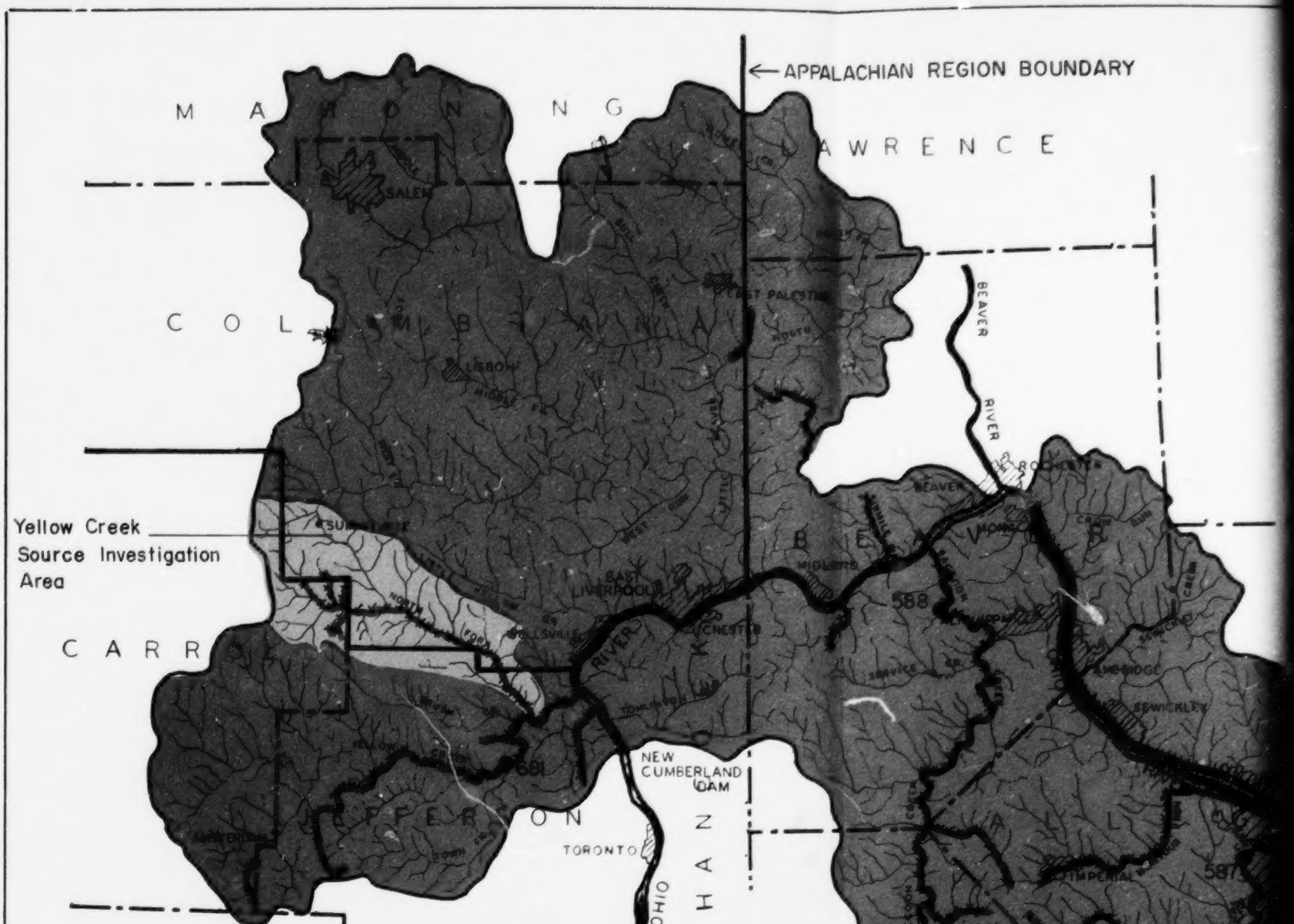
Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Total Manganese (mg/l)	Total Aluminum (mg/l)	Flow (cfs)
10	Min.		6.9	0.0	91.0	80.0	28.0	0.0	0.0	0.0	2.9
	Max.	6	7.7	20.0	119.0	140.0	45.0	2.7	1.5	3.4	300.0
	Avg.			6.2	100.8	116.7	35.7	0.9	0.5	1.2	99.3
11	Min.		6.8	0.0	21.0	35.0	10.0	0.0	0.0	0.0	1.7
	Max.	6	7.4	18.0	42.0	76.0	32.0	3.2	0.2	1.1	77.4
	Avg.			6.8	28.7	45.2	21.3	0.8	0.1	0.4	17.8
174	Min.		3.8	20.0	0.0	205.0	85.0	1.3	1.5	0.0	160.0
	Max.	7	6.7	125.0	15.0	294.0	375.0	71.0	2.8	20.7	186.0
	Avg.			70.4	5.4	246.4	233.6	32.7	2.3	6.3	175.1
175	Min.		6.7	0.0	26.0	747.0	150.0	0.2	1.8	0.8	0.5
	Max.	6	7.4	27.0	53.0	1016.0	750.0	4.8	4.1	19.0	10.0
	Avg.			12.3	37.2	937.2	480.0	2.2	3.0	7.6	4.7
176	Min.		6.6	0.0	69.0	136.0	85.0	1.4	0.3	1.0	6.0
	Max.	6	7.6	25.0	138.0	1061.0	425.0	14.2	5.9	18.3	64.0
	Avg.			7.0	119.0	415.8	206.0	4.1	2.2	4.8	18.9
199	Min.		5.3	0.0	50.0	60.0	5.0	0.5	0.2	0.0	0.0
	Max.	4	7.4	5.0	88.0	94.0	20.0	1.1	1.1	1.9	0.4
	Avg.			1.3	61.3	71.8	13.8	0.7	0.6	0.8	0.1
200	Min.		6.7	0.0	52.0	65.0	14.0	0.2	0.0	0.0	0.1
	Max.	6	7.5	5.0	63.0	104.0	20.0	0.5	0.3	1.5	7.0
	Avg.			0.8	56.8	86.2	17.8	0.3	0.2	0.6	3.9
201	Min.		6.7	0.0	62.0	69.0	2.0	0.5	0.3	0.0	0.1
	Max.	6	7.4	5.0	81.0	98.0	25.0	0.7	0.8	1.0	20.0
	Avg.			1.5	68.8	81.2	15.7	0.6	0.6	0.7	3.8

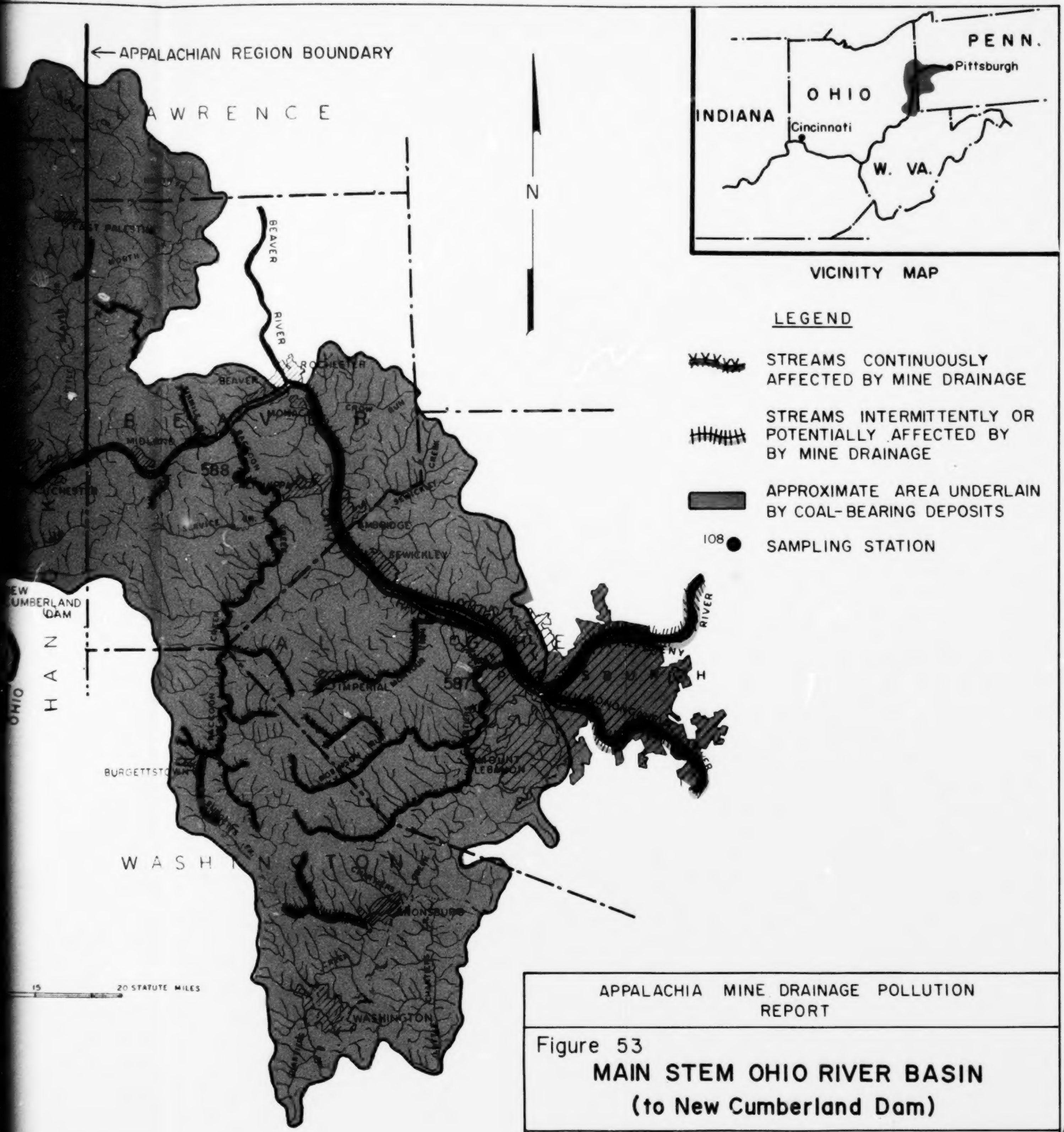
Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Total Manganese (mg/l)	Total Aluminum (mg/l)	Flow (cfs)
202	Min.		7.0	0.0	35.0	46.0	12.0	0.8	0.1	0.1	0.0
	Max.	6	7.2	13.0	60.0	75.0	35.0	4.8	2.4	3.6	80.0
	Avg.			4.7	50.7	63.0	24.2	1.6	0.9	1.5	16.0
203	Min.		6.8	0.0	15.0	22.0	7.0	0.8	0.2	0.9	1.0
	Max.	6	7.2	18.0	51.0	60.0	27.0	2.7	0.7	2.6	90.0
	Avg.			9.2	33.2	44.7	17.7	1.9	0.4	1.6	20.7
587	Min.		6.3	5.0	18.0	522.0	400.0	2.4	2.8	5.5	62.0
	Max.	6	7.1	41.0	75.0	852.0	800.0	9.6	3.6	27.4	80.0
	Avg.			22.3	45.2	604.2	491.7	5.7	3.2	13.6	70.8
588	Min.		3.3	131.0	0.0	345.0	305.0	0.1	1.1	0.0	14.0
	Max.	6	5.1	362.0	0.0	816.0	800.0	7.2	14.7	69.4	57.0
	Avg.			244.8	0.0	627.3	463.3	3.4	8.3	27.4	34.2
681	Min.		6.1	1.0	7.0	262.0	185.0	0.0	0.0	0.2	9.0
	Max.	6	7.4	20.0	18.0	285.0	350.0	2.4	1.0	7.7	25.0
	Avg.			9.2(5)*	13.2(5)	270.2	250.0	0.5	0.6	2.0	14.8
682	Min.		6.7	0.0	66.0	590.0	300.0	0.0	0.3	0.0	9.0
	Max.	6	7.5	22.0	82.0	1005.0	850.0	2.4	2.4	8.1	24.7
	Avg.			6.5	73.0	820.3	510.8	0.7	1.0	2.0	15.1
683	Min.		6.6	0.0	110.0	920.0	300.0	1.1	0.0	4.0	24.0
	Max.	6	7.5	15.0	145.0	2560.0	1750.0	16.8	3.3	16.2	131.0
	Avg.			5.0	127.2	1475.7	698.3	6.7	1.2	10.0	89.7
684	Min.		7.3	0.0	82.0	366.0	345.0	2.4	0.2	0.0	14.0
	Max.	6	8.0	11.0	147.0	1363.0	950.0	7.2	1.1	21.8	29.0
	Avg.			2.0	121.5	1001.8	460.0	3.4	0.4	8.3	22.4

Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Total Manganese (mg/1)	Total Aluminum (mg/1)	Flow (cfs)
685	Min.		4.6	0.0	0.0	730.0	15.0	0.6	1.0	0.0	3.8
	Max.	6	6.6	125.0	17.0	1031.0	450.0	9.6	2.0	24.6	9.0
	Avg.			73.2	8.0	877.8	296.7	4.6	1.5	11.0	7.1
686	Min.		5.3	0.0	5.0	295.0	144.0	0.5	1.3	1.0	1.8
	Max.	6	6.8	61.0	83.0	381.0	500.0	19.2	2.9	4.4	7.0
	Avg.			14.0	48.5	333.8	241.2	4.7	1.7	2.4	4.2
687	Min.		4.0	9.0	0.0	144.0	76.0	0.0	0.6	0.4	0.1
	Max.	6	7.1	178.0	45.0	193.0	750.0	3.8	7.3	9.2	60.0
	Avg.			56.7	24.3	168.7	236.8	1.4	3.4	3.6	19.2
688	Min.		6.7	15.0	7.0	160.0	95.0	0.5	2.8	1.0	0.1
	Max.	6	7.0	37.0	35.0	280.0	270.0	4.1	6.2	3.6	180.0
	Avg.			25.7	24.7	219.8	193.7	2.0	5.0	2.1	35.2
700	Min.		6.8	0.0	17.0	50.0	62.0	1.2	0.6	1.5	8.0
	Max.	6	7.3	28.0	68.0	156.0	85.0	8.7	2.8	10.5	320.0
	Avg.			12.3	45.8	121.8	73.5	3.0	1.7	4.0	98.9
701	Min.		6.2	0.0	22.0	40.0	13.0	0.6	0.1	0.3	0.1
	Max.	6	7.1	27.0	50.0	82.0	30.0	1.8	2.1	2.0	2.0
	Avg.			7.8	31.8	56.2	24.5	1.0	0.6	1.1	0.6
702	Min.		7.2	0.0	91.0	146.0	22.0	0.2	0.1	0.1	1.3
	Max.	6	8.0	27.0	210.0	205.0	40.0	6.4	3.3	9.3	2400.0
	Avg.			7.7	163.2	163.8	33.8	1.4	0.8	2.4	413.2
703	Min.		7.4	14.0	103.0	101.0	28.0	0.0	0.2	0.0	0.1
	Max.	6	8.0	103.0	201.0	230.0	40.0	2.9	0.7	6.7	17.0
	Avg.			39.5	169.0	161.2	35.5	0.7	0.3	1.9	7.3
704	Min.		7.5	0.0	133.0	98.0	31.0	0.1	0.1	0.1	0.0
	Max.	4	8.1	33.0	152.0	190.0	43.0	0.5	1.9	0.8	3.0
	Avg.			18.8	141.3	141.3	36.8	0.4	0.6	0.6	1.3

Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Total Manganese (mg/l)	Total Aluminum (mg/l)	Flow (cfs)
705	Min.		7.6	2.0	103.0	110.0	24.0	0.0	0.0	0.0	0.1
	Max.	6	8.6	42.0	165.0	200.0	55.0	1.0	2.8	2.5	6.0
	Avg.			18.7	130.5	160.0	43.7	0.4	0.7	1.1	3.4
706	Min.		7.4	4.0	90.0	91.0	22.0	0.1	0.0	0.5	0.1
	Max.	5	9.0	37.0	188.0	236.0	45.0	0.6	4.3	1.7	12.4
	Avg.			23.2	132.2	152.6	35.4	0.4	1.0	1.2	5.3
837	Min.		7.2	0.0	111.0	112.0	35.0	0.2	0.2	0.6	0.1
	Max.	2	7.3	9.0	111.0	156.0	35.0	0.4	0.3	0.9	0.1
	Avg.			4.5	111.0	134.0	35.0	0.3	0.3	0.8	0.1
838	Min.		7.6	0.0	20.0	140.0	105.0	0.5	0.7	0.8	13.3
	Max.	2	7.8	0.0	30.0	156.0	115.0	0.5	0.8	1.1	23.7
	Avg.			0.0	25.0	148.0	110.0	0.5	0.8	1.0	18.5
839	Min.		4.0	128.0	0.0	192.0	260.0	0.7	6.6	5.6	27.8
	Max.	2	4.2	130.0	0.0	260.0	265.0	1.0	8.8	12.0	51.0
	Avg.			129.0	0.0	226.0	262.5	0.9	7.7	8.8	39.4

*(5) Indicates the number of samples used in averages when other than the maximum.


APPALACHIAN REGION BOUNDARY
MAHONING
LAWRENCE
COLUMBIANA
CARROLL
JEFFERSON
HANCOCK
BEAVER
ALLEGHENY
WASHINGTON
Yellow Creek Source Investigation Area
SALEM
EAST PALESTINE
LISBON
EAST LIVERPOOL
WELLSVILLE
CHESTER
RIVER
NEW CUMBERLAND DAM
TORONTO
OHIO
BEAVER RIVER
ROCHESTER
BEAVER
MIDLAND
588
681
587
AMBRIDGE
SEWICKLEY
IMPERIAL
BURGETTSTOWN
CANONSBURG
WASHINGTON
SCALE
5
0
5
10
15
20 STATUTE MILES
A

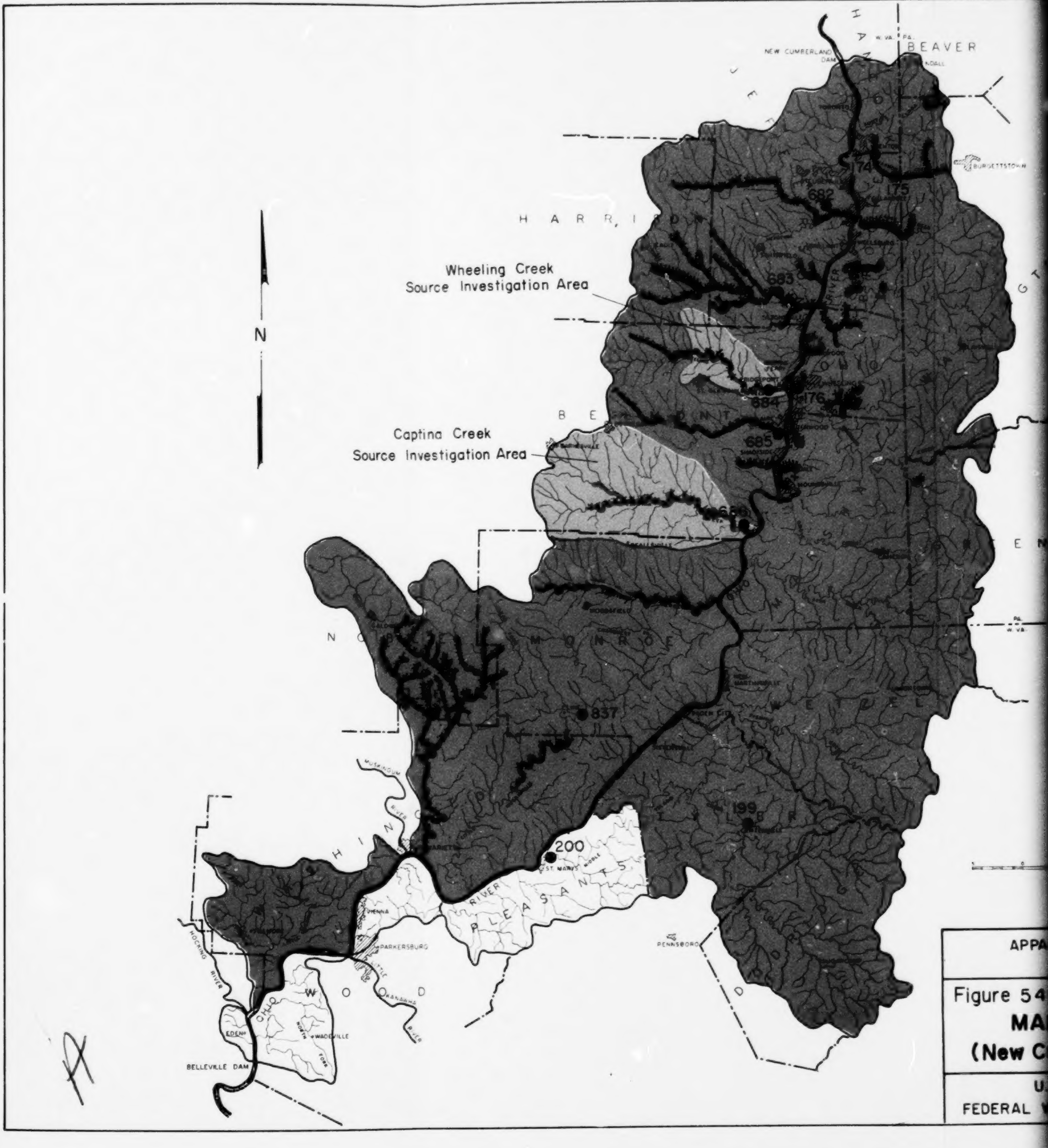

APPALACHIAN REGION BOUNDARY
LAWRENCE
N
BEAVER RIVER
EAST PALESTINE
ROCHESTER
BEAVER
MONACA
CROW RUN
BEAVER
MIDLAND
588
CHESTER
RACCOON
SERVICE
AMBRIDGE
SEWICKLEY
NEW CUMBERLAND DAM
HANCOCK
OHIO
ALLEGHENY
ALLEGHENY RIVER
IMPERIAL
587
PITTSBURGH
MONONGAHELA
MOUNT LEBANON
BURGETTSTOWN
WASHINGTON
MONONGAHELA
WASHINGTON
15
20 STATUTE MILES
PENN.
Pittsburgh
OHIO
INDIANA
Cincinnati
W. VA.
VICINITY MAP
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
108 SAMPLING STATION

APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 53

MAIN STEM OHIO RIVER BASIN (to New Cumberland Dam)

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION


BEAVER
W. VA.
PA.
NEW CUMBERLAND DAM
BURGETTSTOWN
HARRISON
Wheeling Creek
Source Investigation Area
Captina Creek
Source Investigation Area
N
BELMONT
MONROE
NOBLE
174
175
682
683
684
685
686
176
837
199
200
ST. MARYS
PLEASANTS
RIVER
OHIO
WOOD
WETZEL
PA.
W. VA.
PARKERSBURG
VIENNA
MARIETTA
MUSKINGUM RIVER
HOCKING RIVER
KANAWHA RIVER
LITTLE
NORTH FORK
EDEN
WADEVILLE
BELLEVILLE DAM
PENNSBORO
NEW MARTINSVILLE
PADEN CITY

APPA

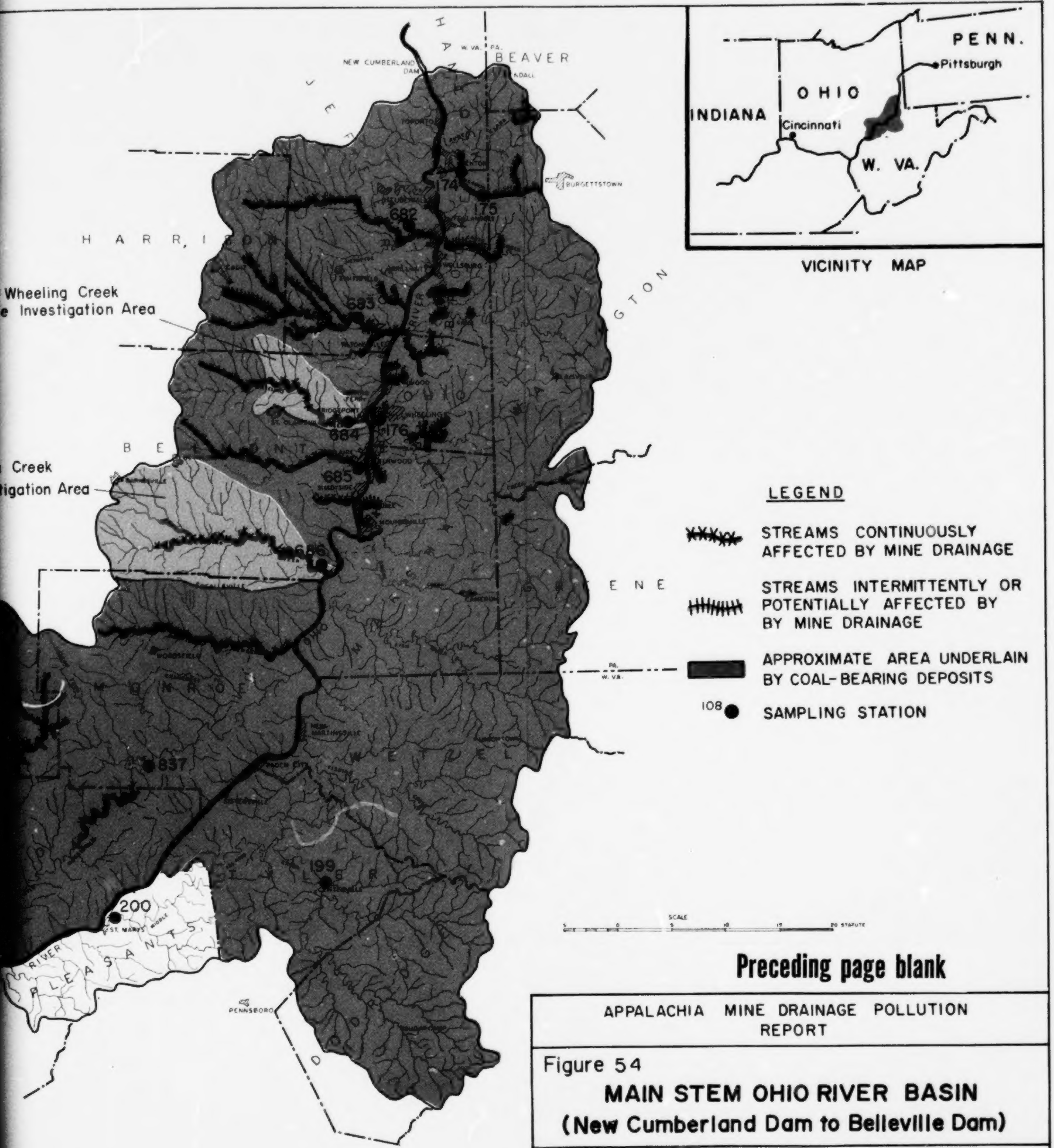
Figure 54

MA

(New C

U.

FEDERAL


NEW CUMBERLAND DAM
W. VA.
PA.
BEAVER
BURGETTSTOWN
H A R R I S O N
Wheeling Creek
Investigation Area
Creek
tigation Area
B E L M O N T
M O N R O E
W E T Z E L
T Y L E R
P L E A S A N T S
G R E E N E
W A S H I N G T O N
D O D D R I D G E
OHIO RIVER
ST. MARYS
PENNSBORO
174
175
176
682
683
684
685
686
837
199
200
PA.
W. VA.
PENN.
Pittsburgh
OHIO
INDIANA
Cincinnati
W. VA.
VICINITY MAP
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
108 SAMPLING STATION
SCALE
5 0 5 10 15 20 STATUTE

Preceding page blank

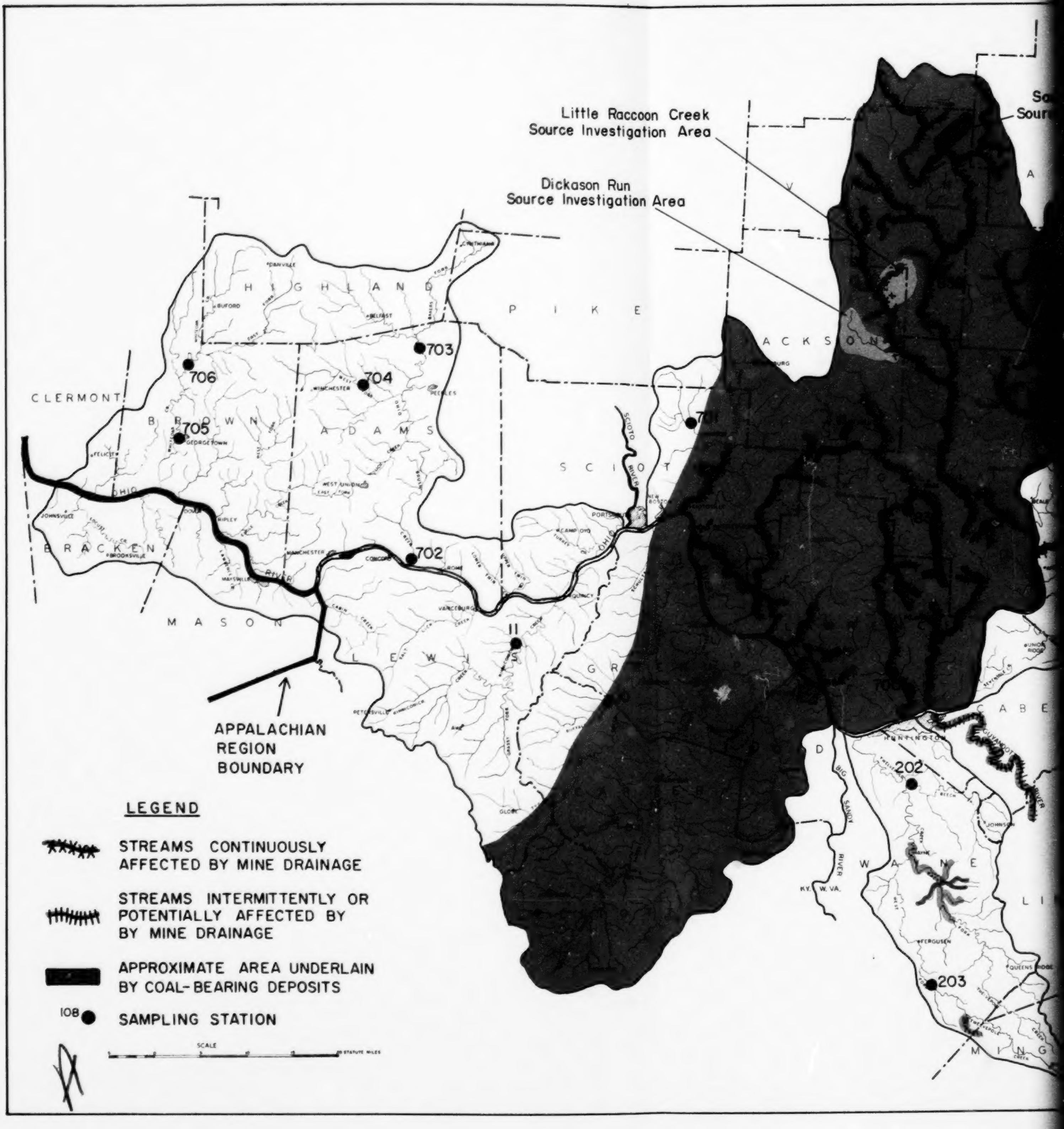
APPALACHIA MINE DRAINAGE POLLUTION REPORT

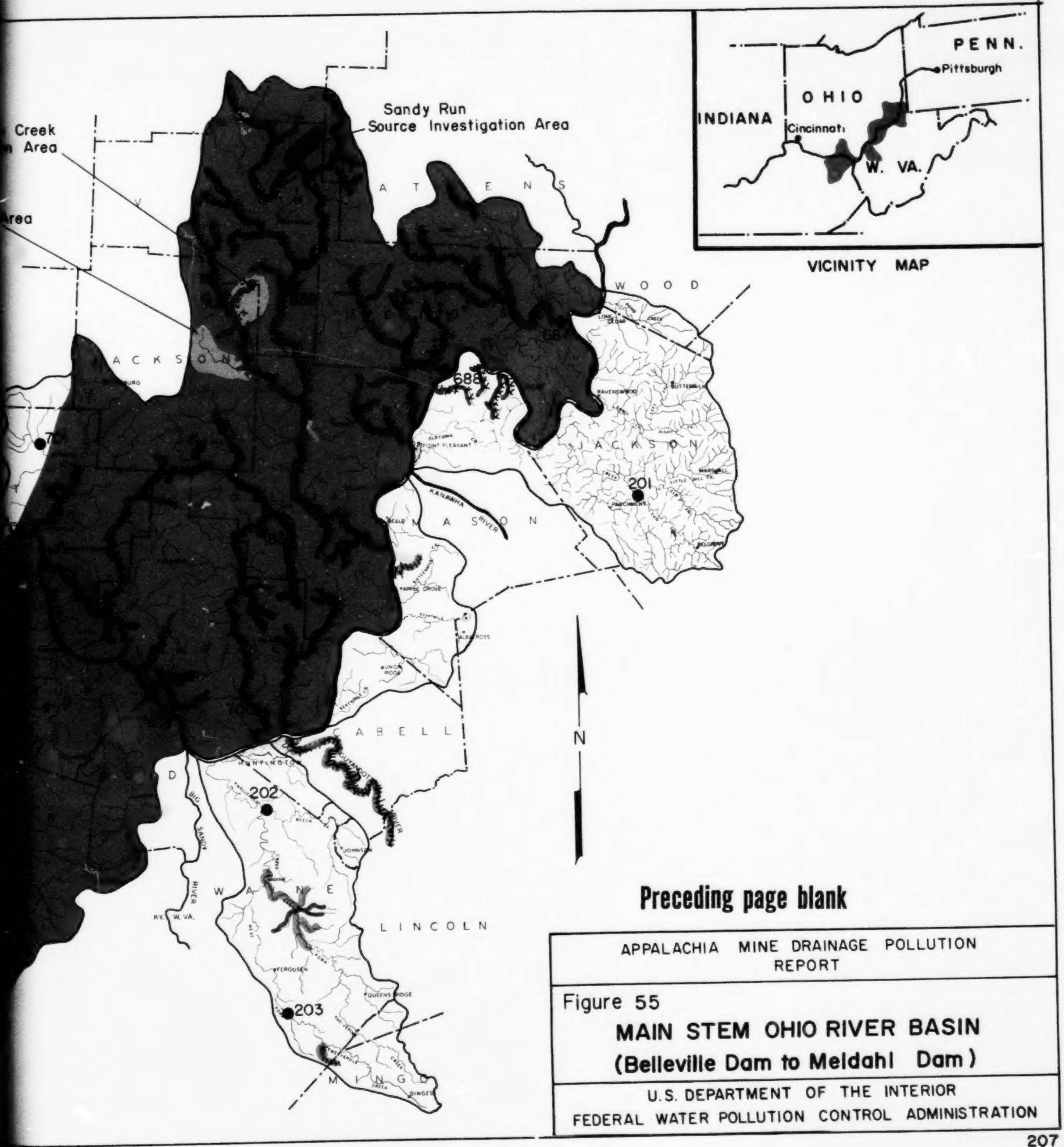
Figure 54

MAIN STEM OHIO RIVER BASIN
(New Cumberland Dam to Belleville Dam)

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

B


Little Raccoon Creek
Source Investigation Area
Dickason Run
Source Investigation Area
HIGHLAND
PIKE
JACKSON
CLERMONT
BROWN
ADAMS
SCIOTO
BRACKEN
MASON
LEWIS
CABELL
WAYNE
MINGO
OHIO RIVER
SCIOTO RIVER
BIG SANDY RIVER
GUYANDOTTE RIVER
KY. W. VA.
HUNTINGTON
PORTSMOUTH
GEORGETOWN
WEST UNION
MAYSVILLE
RIPLEY
MANCHESTER
VANCEBURG
PEEBLES
WINCHESTER
703
704
706
705
702
701
11
202
203
APPALACHIAN
REGION
BOUNDARY
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
108 SAMPLING STATION
SCALE
STATUTE MILES


Sandy Run
Source Investigation Area
Creek
n Area
Area
A T H E N S
J A C K S O N
W O O D
RAVENSWOOD
POINT PLEASANT
J A C K S O N
201
688
M A S O N
KANAWHA RIVER
APPLE GROVE
C A B E L L
HUNTINGTON
202
BIG SANDY RIVER
KY. W. VA.
W A Y N E
L I N C O L N
203
M I N G O
N
PENN.
Pittsburgh
OHIO
INDIANA
Cincinnati
W. VA.
VICINITY MAP

Preceding page blank

APPALACHIA MINE DRAINAGE POLLUTION
REPORT

Figure 55

MAIN STEM OHIO RIVER BASIN
(Belleville Dam to Meldahl Dam)

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

B

Kentucky River Basin

Description

The Kentucky River basin is located in central Kentucky and is entirely within that state. The North Fork of the Kentucky River rises in Letcher County and the Kentucky River leaves Appalachia at the western border of Garrard County.

The Kentucky River basin is south of the glaciated portion of the Ohio River basin. Physical features of the basin are generally controlled by the erosional characteristics of the flat-lying paleozoic rocks that underlie the basin. The drainages of the South, Middle and North Forks of the Kentucky River all rise in the Eastern Kentucky coal field portion of the Appalachian Plateau.

Important coal reserves are present in Letcher, Leslie, Harlan, Knott, Perry, Breathitt, and Clay Counties. Coal bearing beds in the Kentucky basin are in Lee and Breathitt Formations of Pennsylvanian age. These coal-bearing rocks consist mainly of alternating beds of sandstone, siltstone, shale, coal and underclay. The Breathitt Formation is from 1,300 feet thick to 2,500 feet thick and contains 23 principal coal beds, including the Elkhorn No. 1, 2, and 3 coal beds and the Hazard coal beds (Huddle and others, 1963).

Coal has been produced in this area for over 100 years, but large-scale production has been limited to the past 50 years. Production is mostly from Letcher, Perry and Clay Counties. Locally, all coal beds are accessible by drift entry, which is the principal mining method in the area. Combination strip mining and auger mining is also widely practiced, particularly in Perry County. Large stripping operations are limited to a few areas.

Mine Drainage Sources and Their Effect on Stream Quality

The number of coal mine drainage pollution sources in the Kentucky River basin is not known. There are 10,000 acres of unreclaimed surface mined land in the basin.

Limited U.S. Geological Survey data from a water quality station at Hazard, Kentucky, indicate that the sulfate load in the North Fork at Hazard is in the order of 100 tons/day, 75 tons of which may result from acid mine drainage. Other sources of mine drainage below Hazard contribute in the order of 80 tons/day of sulfate to the Kentucky River. The total of 155 tons/day of sulfate considered to originate from mine drainage indicates the rate of formation of mine drainage acidity in the Kentucky River basin as compared to other areas discussed.

As shown in Figure 56 and by the analyses in Table 23 portions

Preceding page blank

of the Kentucky River and numerous tributary streams are continuously or intermittently polluted by mine drainage waters. A total of at least 495 miles of streams within the Kentucky River basin are considered significantly polluted by mine drainage on the basis of stream samples obtained during 1966 and on the basis of published reports and communication with other Federal and State agencies.

Mine drainage pollution occurs primarily in four portions of the Kentucky River basin in association with the mining activity in those areas. The four areas are the headwaters area of the North Fork of the Kentucky River in Letcher County, the Carrs Fork-Lotts Creek-Troublesome Creek area in Perry and Knott Counties, the Middle Fork Kentucky River area in Leslie County, and the South Fork Kentucky River area in Clay County (Fig. 56). The streams determined to be significantly affected by coal mine drainage in the Kentucky River basin are listed in Table 22.

Table 22 Streams in Kentucky River Basin Determined to be Significantly Polluted by Coal Mine Drainage.

Stream	County	Map Station No. (Figure 56)
*Quillen Fork	Letcher	560
Yonts Fork	"	561
Wright Fork	"	562
Millstone Creek	"	564
Smoot Creek	"	565
Rockhouse Creek	"	559, 548
North Fork Kentucky River	"	549
(portions)	"	
" " " "	Perry	536
" " " "	Breathitt	542
" " " "	Lee	514
Leatherwood Creek	Perry	546
Carrs Fork	Knott, Perry	558, 552
Irishman Creek	Knott	557
*Sassafras Creek	Knott	556
*Yellow Creek	Knott	555
*Stacy Branch	Knott	554
Acup Creek	Perry	553
Buckeye Creek	Perry	551
Buffalo Creek	Perry	544
*Raccoon Creek	Perry	543
Trace Creek	Knott	533
*Lotts Creek	Perry	535
*Jake Creek	Knott	532
*Big Creek	Perry	523
Buckhorn Creek	Breathitt	
Troublesome Creek	Breathitt	531
Quicksand Creek	Breathitt	516

Stream	County	Map Station No. (Figure 56)
Middle Fork Kentucky River	Leslie	526
Hurts Creek	Leslie	525
Cutshin Creek	Leslie	524
Red Bird River	Clay	527
Horse Creek	Clay	528
Goose Creek	Clay	529
Little Goose Creek	Clay	530
Grays Fork	Clay	No station
Kentucky River	Lee	
Kentucky River (portions)	Estill	510

*Indicates severly polluted streams

Severe mine drainage pollution was found to exist in small tributary streams such as Quillen Fork, Sassafras Creek, Yellow Creek, Stacy Branch, Raccoon Creek, Lotts Creek, Jake Creek and Big Creek (See Table 22 for station numbers and Figure 56 for map locations). The severity of mine drainage pollution in the Kentucky basin decreases rapidly downstream as such small tributaries merge with other slightly polluted or unpolluted streams, but the alkalinity of water in the Kentucky River may be reduced below desirable natural levels by acid mine water at least as far downstream as Irvine in Estill County (Sta. 510, Fig 56).

A. Headwaters Area North Fork Kentucky River

The Elkhorn No. 3 coal seam has been surface mined by rim cut in this area and refuse has been disposed of on the slopes below the mines. In many cases these refuse piles are on stream banks and drainage and silt from them enters directly into the streams.

Quillen Fork (Sta. 560) near the headwaters of the North Fork Kentucky River was acid throughout the study and had pH values between 2.7 and 4.9. Below the junction of Quillen Fork with Yonts Creek (Sta. 561) the acidity intermittently exceeded the alkalinity and concentrations of mine drainage indicators were high at all times.

Millstone Creek (Sta. 564), Smoot Creek (Sta. 564) and Rockhouse Creek (Stas. 559 and 548) were other streams found to be significantly affected by mine drainage in this area.

B. Carrs Fork-Lotts Creek-Troublesome Creek Area

In this area in Perry and Knott Counties, there has been extensive surface and underground mining of the Hazard No. 4 and Hazard No. 9 coal seams. There are presently six active deep mines, five active auger mines, and two active combination strip and auger mines in the area. There are 11 known inactive underground mines with between 50 and 80 unsealed openings and 23 refuse piles, and two inactive surface mines in the area.

Various tributaries to Carrs Fork (Sta. 552) and Lotts Creek (Sta. 535) are continuously and severely polluted by coal mine drainage (Fig 56 and Table 23). Yellow Creek (Sta. 555), for example, had pH values ranging between 2.8 and 4.6 and average acidity of 566 mg/l, with zero alkalinity. Carrs Fork and Lotts Creek are less acid than some of their tributaries, but the average concentrations of various indicators such as iron and manganese are well above desirable limits in these two streams.

It is believed that the most severe pollution in this area occurs during periods of high runoff, when slugs of pollution enter the streams. These conditions were not encountered at the times of sampling.

C. Middle Fork Kentucky River Area

In this area near Hyden in Leslie County there are only a few small mines in operation and these are mainly underground ones.

Stream pollution in this area is not severe in comparison with the other areas described. However, periodic degradation of some streams is evidenced by some samples collected at stations 524 (Cutshin Creek), 525 (Hurts Creek), and 526 (Middle Fork Kentucky River) in which concentrations of mine drainage indicators exceeded desirable levels.

D. South Fork Kentucky River

In the drainage area of South Fork Kentucky River near Manchester, Kentucky, there has been extensive surface and underground mining of the Horse Creek coal seam, and resultant mine drainage pollution of streams in the area.

Horse Creek (Sta. 528) and Little Goose Creek (Sta. 530), tributaries to Goose Creek, were polluted throughout the study. Generally, pH values in these streams were below 6.5 and minimum values were 4.2 in Horse Creek and 5.8 in Goose Creek. Goose Creek and sections of the South Fork below Manchester are reported to be acid on occasions. Fish kills are reported to have resulted from mine drainage pollution in Goose Creek.

Table 23 - Stream Quality Data, Kentucky River Basin

Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Manganese (mg/1)	Aluminum (mg/1)	Flow (cfs)
503	Min.		6.4								
	Max.	1		0.0	42.0	152.0	72.0	0.4	--	--	--
	Avg.										
504	Min.		7.0								
	Max.	1		8.0	196.0	240.0	55.0	0.2	--	--	--
	Avg.										
505	Min.		7.6								
	Max.	1		6.0	36.0	92.0	10.0	3.0	--	--	--
	Avg.										
510	Min.		7.0								
	Max.	1		33.0	26.0	84.0	30.0	2.2	--	--	--
	Avg.										
513	Min.		7.6								
	Max.	1		19.0	20.0	64.0	15.0	8.1	--	--	--
	Avg.										
514	Min.		6.6								
	Max.	1		13.0	21.0	76.0	22.0	5.8	--	--	--
	Avg.										
516	Min.		6.8								
	Max.	1		6.0	58.0	80.0	18.0	0.7	--	--	--
	Avg.										
523	Min.		4.1		0.0						
	Max.	7		175.0	20.0	475.0	696.0	221.0	12.0	143.0	83.0
	Avg.			76.8	4.8(6)*	305.8(6)	326.7(6)	34.8	5.1(6)	29.9(6)	28.5
524	Min.		5.9		22.0						
	Max.	6		42.0	76.0	144.0	220.0	3.9	0.1	5.0	20.0
	Avg.			12.5	39.6(5)	76.8(5)	60.4(5)	1.0	0.1(5)	2.3(5)	12.2(4)
525	Min.		6.0		5.0						
	Max.	6		76.0	108.0	180.0	204.0	6.7	0.1	13.0	5.0
	Avg.			18.3	67.8(5)	139.6(5)	122.8(5)	1.7	0.1(5)	4.5(5)	1.5

*(6) Indicates the number of samples used in averages when other than the maximum.

Table 23 - Stream Quality Data, Kentucky River Basin (cont'd)

Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Manganese (mg/1)	Aluminum (mg/1)	Flow (cfs)
526	Min.		6.2								
	Max.	1		49.0	16.0	44.0	6.0	0.6	--	--	--
	Avg.										
527	Min.		6.2								
	Max.	1		36.0	20.0	84.0	9.0	0.2	--	--	--
	Avg.										
528	Min.		4.2		0.0						
	Max.	7		132.0	18.0	272.0	460.0	4.5	9.7	7.0	61.0
	Avg.			40.8	9.0(6)*	147.5(6)	128.2(6)	2.8	4.2(6)	2.9(6)	12.0
529	Min.		5.8		10.0						
	Max.	7		64.0	42.0	176.0	200.0	1.8	3.3	2.2	710.0
	Avg.			17.6	20.0(6)	86.3(6)	52.7(6)	1.0	1.0(6)	0.7(6)	163.9(5)
530	Min.		5.5		0.0						
	Max.	7		60.0	15.0	188.0	230.0	1.3	3.3	2.3	98.0
	Avg.			16.1	9.8(6)	147.0(6)	103.3(6)	0.6	2.0(6)	1.3(6)	21.8
531	Min.		4.3		0.0						
	Max.	6		96.0	26.0	328.0	210.0	20.0	3.5	18.0	150.0
	Avg.			25.5	10.8(5)	188.8(5)	118.6(5)	4.2	1.3(5)	5.8(5)	42.7
532	Min.		4.2		0.0						
	Max.	7		340.0	54.0	728.0	750.0	9.7	2.4	17.0	12.9
	Avg.			85.8	17.3(6)	506.7(6)	459.7(6)	3.8	1.6(6)	6.6(6)	4.3
533	Min.		5.2		1.0						
	Max.	7		250.0	120.0	452.0	500.0	6.0	1.3	10.0	18.5
	Avg.			56.8	65.5(6)	322.7(6)	269.7(6)	2.2	0.8(6)	3.4(6)	5.5
534	Min.		3.0		0.0						
	Max.	7		860.0	30.0	784.0	1820.0	70.0	11.0	33.0	72.0
	Avg.			277.4	6.3(6)	478.0(6)	968.7(6)	24.2	6.3(6)	21.3(6)	25.2
535	Min.		3.2		0.0						
	Max.	7		405.0	30.0	644.0	780.0	39.0	8.5	29.0	91.0
	Avg.			129.1	9.2(6)	425.3(6)	471.7(6)	11.7	4.5(6)	15.3(6)	34.0

*(6) Indicates the number of samples used in averages when other than the maximum.

Table 23 - Stream Quality Data, Kentucky River Basin

Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Manganese (mg/1)	Aluminum (mg/1)	Flow (cfs)
536	Min.		5.8		18.0						
	Max.	7		67.0	102.0	256.0	220.0	20.0	0.6	18.0	2050.0
	Avg.			16.0	40.5(6)*	150.7(6)	103.3(6)	4.8	0.2(6)	5.6(6)	488.0(5)
541	Min.		6.3								
	Max.	1		48.0	27.0	88.0	60000.0	0.5	--	--	--
	Avg.										
542	Min.		6.0								
	Max.	1		7.0	27.0	120.0	80.0	0.2	--	--	--
	Avg.										
543	Min.		3.6		0.0						
	Max.	7		270.0	20.0	594.0	750.0	8.2	7.2	11.7	10.5
	Avg.			102.3	3.3(6)	416.2(6)	385.5(6)	4.4	2.9(6)	6.3(6)	2.2
544	Min.		3.2		0.0						
	Max.	7		268.0	10.0	676.0	1450.0	24.0	9.7	26.0	7.1
	Avg.			193.0	2.3(6)	432.3(6)	821.0(6)	10.6	7.9(6)	18.6(6)	2.4
545	Min.		6.1		22.0						
	Max.	7		30.0	96.0	144.0	50.0	1.5	0.1	2.4	17.5
	Avg.			10.8	59.2(6)	97.3(6)	14.7(6)	0.5	0.1(6)	1.0(6)	5.1
546	Min.		6.5								
	Max.	1		0.0	37.0	68.0	37.0	--	--	--	--
	Avg.										
547	Min.		6.4								
	Max.	1		0.0	38.0	84.0	32.0	--	--	--	--
	Avg.										
548	Min.		6.5								
	Max.	1		4.0	13.0	124.0	134.0	--	--	--	--
	Avg.										
549	Min.		6.1								
	Max.	1		0.0	42.0	104.0	92.0	--	--	--	--
	Avg.										

*(6) Indicates the number of samples used in averages when other than the maximum.

Table 23 - Stream Quality Data, Kentucky River Basin

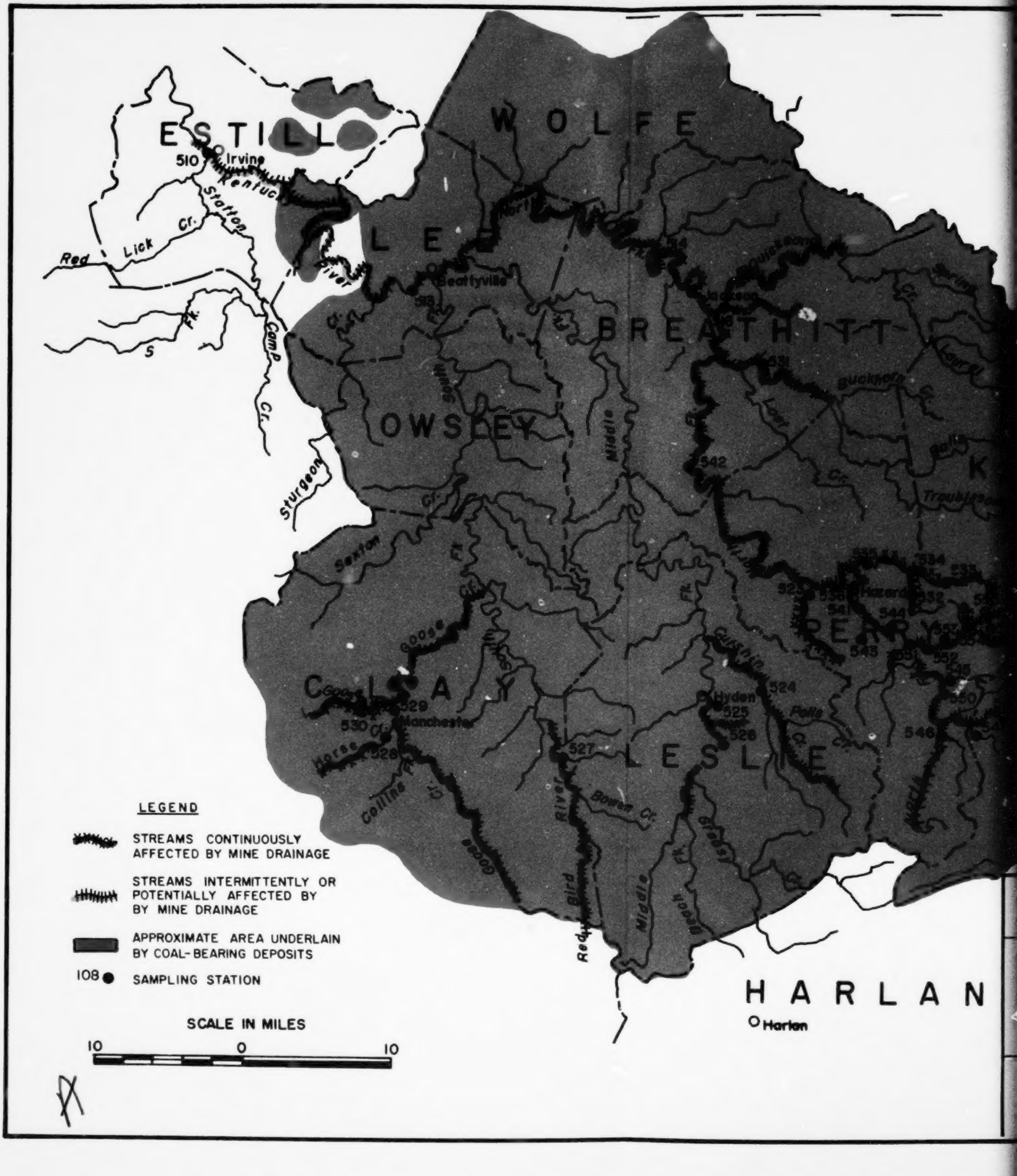
Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Manganese (mg/1)	Aluminum (mg/1)	Flow (cfs)
550	Min.	1	6.3								
	Max.			0.0	37.0	100.0	37.0	--	--	--	--
	Avg.										
551	Min.	6	5.4		26.0						
	Max.			35.0	106.0	332.0	280.0	3.6	0.6	4.0	6.4
	Avg.			7.3	62.4(5)*	237.2(5)	130.6(5)	1.1	0.3(5)	1.9(5)	1.5
552	Min.	7	5.2		4.0						
	Max.			64.0	64.0	302.0	350.0	9.0	2.5	8.4	201.0
	Avg.			21.8	21.8(6)	167.0(6)	157.0(6)	2.7	1.1(6)	2.6(6)	74.0
553	Min.	6	3.7		0.0						
	Max.			180.0	38.0	1032.0	1100.0	75.0	4.8	5.4	5.8
	Avg.			55.5	9.8(5)	532.0(5)	532.0(5)	14.0	3.0(5)	3.6(5)	1.8
554	Min.	7	2.9		0.0						
	Max.			452.0	30.0	390.0	640.0	49.0	4.6	40.0	7.3
	Avg.			240.7	6.7(6)	317.0(6)	503.3(6)	26.7	4.1(6)	25.3(6)	2.2
555	Min.	7	2.7		0.0						
	Max.			910.0	6.0	600.0	970.0	88.0	8.2	47.0	5.5
	Avg.			565.8	1.0(6)	434.3(6)	696.0(6)	46.3	7.1(6)	29.7(6)	1.9
556	Min.	7	3.1		0.0						
	Max.			464.0	68.0	456.0	430.0	21.5	9.3	30.1	4.8
	Avg.			159.8	11.3(6)	259.3(6)	211.7(6)	4.2	5.4(6)	13.1(5)	1.9
557	Min.	1	5.5								
	Max.			38.0	19.0	88.0	90.0	0.3	--	--	4.9
	Avg.										
558	Min.	8	5.5		19.0						
	Max.			100.0	106.0	116.0	464.0	2.4	0.2	4.3	88.0
	Avg.			22.5	52.8(7)	88.3(6)	103.5(6)	0.9(7)	0.1(6)	2.0(6)	29.8(7)
559	Min.	7	4.4		0.0						
	Max.			145.0	110.0	488.0	1730.0	24.8	3.8	8.4	32.0
	Avg.			37.1	32.5(6)	223.7(6)	448.8(6)	8.7	1.6(6)	4.7(6)	12.1(6)

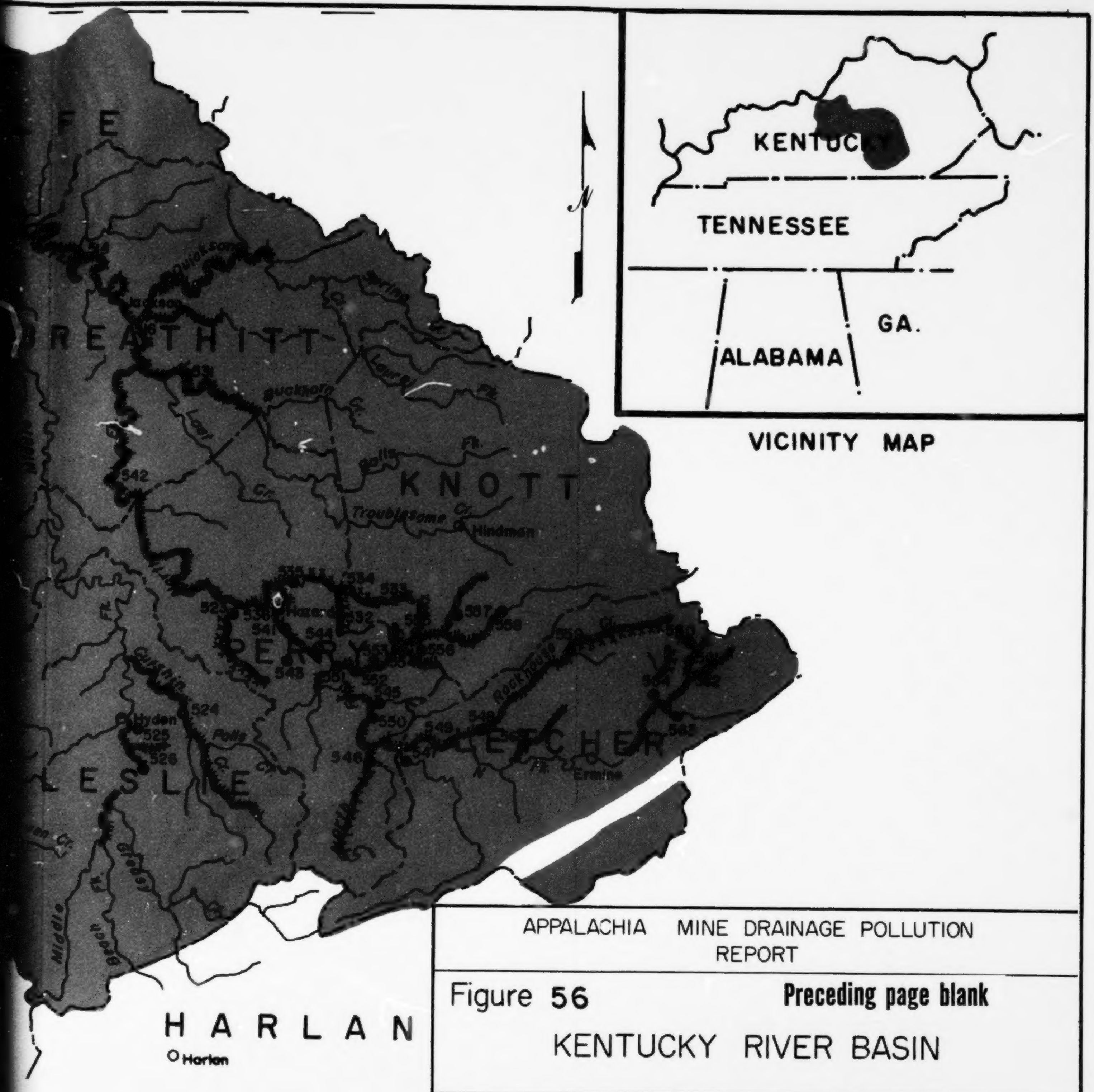
*(5) **Indicates the number of samples used in averages when other than the maximum.**

Table 23 - Stream Quality Data, Kentucky River Basin

Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Manganese (mg/1)	Aluminum (mg/1)	Flow (cfs)
560	Min.		3.0		0.0						
	Max.	6		668.0	50.0	508.0	840.0	113.5	7.0	58.5	2.1
	Avg.			375.0	8.3	312.0	555.0	41.3	4.1	33.4	1.1
561	Min.		5.0		0.0						
	Max.	7		248.0	296.0	348.0	460.0	116.0	3.4	43.2	8.3
	Avg.			48.5(6)*	140.3(6)	250.0(6)	315.2(6)	20.3	1.1(6)	13.8(6)	3.9
562	Min.		6.5		124.0						
	Max.	6		25.0	296.0	276.0	200.0	31.7	1.4	23.0	10.3
	Avg.			4.7	186.4(5)	210.4(5)	138.4(5)	5.6	0.4(5)	5.6(5)	4.5(5)
563	Min.		6.6								
	Max.	1		0.0	78.0	144.0	80.0	0.2	--	--	--
	Avg.										
564	Min.		6.5		106.0						
	Max.	6		6.0	230.0	388.0	688.0	38.7	3.1	48.8	13.8
	Avg.			1.8	157.2(5)	292.0(5)	375.6(5)	6.9	0.8(5)	10.3(5)	6.5
565	Min.		5.6		10.0						
	Max.	6		84.0	82.0	296.0	308.0	93.5	3.4	160.0	9.5
	Avg.			25.0	32.0(5)	197.6(5)	165.2(5)	17.8	1.3(5)	35.0(5)	3.5
620	Min.		7.1								
	Max.	1		16.0	209.0	260.0	20.0	0.2	--	--	--
	Avg.										
621	Min.		6.9								
	Max.	1		0.0	137.0	160.0	30.0	0.3	--	--	--
	Avg.										

*(6) Indicates the number of samples used in averages when other than the maximum.


ESTILL
WOLFE
LEE
BREATHITT
OWSLEY
CLAY
LESLIE
PERRY
HARLAN
Harlan
Irvine
Beattyville
Jackson
Hazard
Hyden
Manchester
Kentucky River
Station Camp Cr.
Red Lick Cr.
S. Fk.
Sturgeon Cr.
Sexton Cr.
Goose Cr.
Collins Fk.
Horse Cr.
Red Bird River
Bowen Cr.
Middle Fk.
Greasy Cr.
Beech Fk.
Cutshin Cr.
Quicksand Cr.
Buckhorn Cr.
Troublesome
Laurel
510
529
530
528
527
524
525
526
542
531
523
541
543
544
545
546
550
552
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
108 SAMPLING STATION
SCALE IN MILES
10
0
10


BREATHITT
KNOTT
PERRY
LESLIE
LETCHER
HARLAN
Harlan
Hyden
Hazard
Hindman
Jackson
Ermine
Quicksand
Buckhorn
Lost
Laurel
Troublesome Cr.
Rockhouse
Cutshin
Middle Fk.
Beech
542
524
525
526
536
541
544
546
548
549
550
552
545
N
KENTUCKY
TENNESSEE
GA.
ALABAMA
VICINITY MAP

APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 56

Preceding page blank

KENTUCKY RIVER BASIN

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

Cumberland River Basin

Description

The Cumberland River is formed by the confluence of the Poor and Clover Forks near Harlan, Kentucky in Appalachia (Fig. 57). From that point, it flows southwesternly into Tennessee, leaving Appalachia at the western border of Smith County, Tennessee. The total area of the Cumberland basin is 17,914 square miles about 60 percent of which is in Appalachia. The Cumberland basin is bounded on the south by the Tennessee River basin and on the north by the Kentucky and Green River basins.

The upper Cumberland basin, above Lake Cumberland, is in the Cumberland Mountains, where the Cumberland and its tributaries flow in deep narrow valleys and have gradients of 10 to 12 feet per mile. In the remainder of the Cumberland basin in Appalachia, the terrain is hilly and the streams have gradients of 3 to 5 feet per mile.

The main coal producing counties in the Kentucky portion of the Cumberland basin are Harlan, Bell, Knox, McCreary, Whitley, Laurel, Jackson, Pulaski and Rockcastle. Important coal producing counties in Tennessee are Clairborne, Campbell, Scott, Fentress and Overton.

In the Kentucky portion of the Cumberland basin, coal is contained in the Lee and Breathitt Formations of Pennsylvanian age. The Lilly coal bed forms the boundary between these geologic units, the Lee Formation being the older. The Hazard and Harlan coal beds occur in the Breathitt Formation. In the Tennessee portion of the Cumberland basin the main coal bearing beds are in Gizzard, Crab Orchard Mountain, Crooked Fork, Slatestone, Indian Bluff, Gravel Gap and Redoak Mountain Groups (Luther, 1959).

Coal mining in the Cumberland basin began in the late 1700's, and has varied in intensity since that time, peak production periods coming in the period from 1910 through the middle 1940's. Production today is considerably less than during peak periods.

Coal mining in this area has been, much as in the Kentucky basin, primarily by drift mining. Strip mining has been particularly important in Bell, Knox, and Laurel Counties, Kentucky, and Fentress County, Tennessee. Combination strip and auger mining is particularly important in Harlan County, Kentucky. Contour strip mining has been widely practiced in preparation for more extensive underground mining.

Preceding page blank

Table 24 (cont'd)

Stream	County	Map Station Number (Fig. 57)
Brush Creek	Knox, Ky.	581
Patterson Creek	Whitley, Ky.	607
*Clear Fork	Clairborne, Tenn.	598
Straight Creek	Bell, Ky.	599
Clear Fork	Whitley, Ky.	606
Clear Fork	Clairborne and Campbell, Tenn.	598, 600
Stinking Creek	Campbell, Tenn.	604
Hickory Creek	Campbell, Tenn.	603, 602
White Oak Creek	Campbell, Tenn.	601
Pleasant Run	Whitley, Ky.	612
Jellico Creek	Whitley, Ky.	611
Marsh Creek	McCreary, Ky.	614
*Raccoon Creek	Laurel, Ky.	539
Little Raccoon Creek	Laurel, Ky.	538
Wood Creek	Laurel, Ky.	537
Beaver Creek	McCreary, Ky.	630
Hall Creek	Scott, Tenn.	642
Brimstone Creek	Scott, Tenn.	640
Buffalo Creek	Scott, Tenn.	637
*Flat Creek	Scott, Tenn.	636
*Sulphur Creek	Scott, Tenn.	635
Phillips Creek	Scott, Tenn.	638
New River	Scott, Tenn.	639
Davis Creek	Fentress and Scott, Tenn.	641
*Rock Creek	McCreary, Ky.	617
South Fork	McCreary, Ky.	615
Wolf Creek	McCreary, Ky.	616
*Meadow Creek	Putnam, Tenn.	650
W. Fork Obey River	Overton, Tenn.	645
*Cub Creek	Overton, Tenn.	646
*Little Laurel Creek	Fentress, Tenn.	647
*E. Fork Obey River	Overton and Fentress, Tenn.	648, 649
*Officer Creek	Putnam, Tenn.	651

*Severely Polluted Streams

Beginning in the headwaters area of the Cumberland basin, significant mine drainage pollution is first found in the Poor Fork (Sta. 566), where iron concentrations averaged nearly 3 mg/l and sulfate concentrations as high as 460 mg/l were measured.

There has been extensive mining of the Mason coal seam in the Cranks Creek watershed Harlan County, Kentucky, and the resultant mine drainage significantly affects Cranks Creek (Sta. 572) and Martins Fork (Stas. 570 and 571). Values of pH as low as 4.2 were measured in Cranks Creek.

Proceeding downstream the next major damaged area is the watershed of Yellow Creek, where extensive surface and underground mining in the Stony Fork (Stas. 597 and 595) and Bennetts Fork (Sta. 596) watersheds has caused intermittent pollution of these streams.

In the Straight Creek watershed, Bell and Harlan Counties, Kentucky, there has been extensive mining of the Crockett coal seam in the Left Fork drainage (Sta. 578) and of the Hazard No. 9 and Hazard No. 7 coal seams in the Right Fork drainage. Mine drainage pollution is most severe in the Left Fork, where pH values as low as 4.2 were measured.

In the Clear Fork drainage basin, Clairborne and Campbell Counties, Tennessee, and Whitley County, Kentucky, Straight Creek (Sta. 599), White Oak Creek (Sta. 601) Hickory Creek (Stas.602 and 603), and Stinking Creek (Sta. 604) as well as the Clear Fork (Stas. 598, 600, and 606) were observed to be significantly degraded by mine drainage.

Along the Clear Fork, recent mining appears to be underground mining in Tennessee, but a coal processing plant and several refuse piles are contributing pollution into the Clear Fork in Kentucky.

In the Hickory Creek watershed, almost the entire rim of the White Oak Creek drainage basin has been strip mined and the waste has been cast down the slopes. The measured pH values in White Oak Creek (Sta. 601) did not fall below 5.8, but the stream appeared to be devoid of aquatic life. Values of pH as low as 4.2 were measured in Stinking Creek (Sta. 604).

Pleasant Run and Jellico Creek in the lower Jellico Creek basin are severely degraded by mine drainage. In the portion of Pleasant Run between stations 612 and 613 (Fig. 57) the Stearns coal seam has been strip mined in the flood plain and across the stream. The pH at station 612 fell as low as 2.8 and did not exceed 4.0.

Inactive underground and surface mines that remain after mining of the Lilly coal seam are the source of mine drainage pollution in Raccoon Creek (Sta. 538) and Little Raccoon Creek (Sta. 539). Although extensive mining ceased some time ago, these streams are still acid most of the time. The pH values in Raccoon Creek ranged generally between 4.5 and 6.2 and those in Little Raccoon Creek ranged generally between 4.8 and 5.9.

In the New River drainage basin, Tennessee, many small streams are severely polluted by mine drainage that originates chiefly in inactive mines. Data from sampling stations on Flat Creek (Sta. 636) and Sulphur Creek (Sta. 635) examplify the severity of pollution in this area. The pH values measured at these stations ranged between 2.9 and 4.8. Pollution from the minor tributaries periodically lowers the alkalinity and pH in the New River (Sta. 639) to below desirable levels and increases the concentration of iron to above desirable levels.

Relatively serious mine drainage pollution exists in the Cumberland National Forest, McCreary County, Kentucky. Mining has been carried on in the Rock Creek drainage area since the early 1900's and most of the pollution load is apparently from refuse piles in this area. Data from sampling station 617 on Rock Creek indicate that the pH of this stream is below 6.0 most of the time and values as low as 3.3 were measured.

The area most severely degraded by mine drainage in Tennessee is the Obey River basin. In the West Fork watershed, Cub Creek (Sta. 646) is the only highly acid stream. At and just below the junction of Cub Creek with the West Fork, damage to the West Fork is apparent, particularly from iron precipitates.

The East Fork of the Obey River is severely degraded by mine drainage and is devoid of fish and other aquatic life from its headwaters to near the point where it enters Dale Hollow Reservoir, a distance of about 30 miles. Measured pH values in the East Fork did not exceed 3.4 at station 648 and were as low as 4.3 at station 643 just above Dale Hollow Reservoir. Highly polluted tributaries to the East Fork include Meadow Creek (Sta. 650), Little Laurel Creek (Sta. 647), and Officer Creek (Sta. 651). Serious reduction of fish populations in the East Fork of Dale Hollow have been reported by the Tennessee Department of Fish and Game.

Table 25 - Water Quality Data, Cumberland River Basin

Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Manganese (mg/1)	Aluminum (mg/1)	Flow (cfs)
537	Min.		5.9		8.0						
	Max.	6		63.0	70.0	200.0	186.0	1.4	2.2	1.5	4.3
	Avg.			16.4(5)*	46.8	162.8(5)	86.8(5)	0.7	1.3(5)	1.1(5)	2.7(4)
538	Min.		4.8		2.0						
	Max.	6		165.0	11.0	204.0	238.0	1.9	5.5	1.9	13.0
	Avg.			50.7	4.6(5)	151.6(5)	151.0(5)	0.6	3.4(5)	1.3(5)	5.0
539	Min.		4.5		0.0						
	Max.	7		256.0	14.0	214.0	696.0	1.3	10.4	7.5	35.0
	Avg.			88.6	6.3(6)	147.0(6)	192.2(6)	0.6	5.3(6)	3.3(6)	13.3
540	Min.		6.1								
	Max.	1		38.0	15.0	52.0	32.0	1.0	-	-	-
	Avg.										
566	Min.		6.0		64.0						
	Max.	4		5.7	360.0	132.0	460.0	10.9	22.5	2.0	914
	Avg.			20.0	157.7	101.0	170.0	3.7	5.7	1.1	825(2)
567	Min.		7.1								
	Max.	1		0.0	199.0	120.0	80.0	0.2	-	-	-
	Avg.										
568	Min.		6.4								
	Max.	1		0.0	52.0	60.0	38.0	0.2	-	-	-
	Avg.										
569	Min.		6.6								
	Max.	1		0.0	43.0	72.0	64.0	0.2	-	-	-
	Avg.										
570	Min.		6.6								
	Max.	1		0.0	41.0	48.0	45.0	0.4	-	-	-
	Avg.										
571	Min.		5.6		26.0						
	Max.	6		88.0	42.0	84.0	30.0	1.6	0.2	2.5	54.0
	Avg.			18.0(5)	32.6(5)	59.2(5)	24.8(5)	1.2(5)	0.2(5)	1.7(5)	35.2(5)

*(5) Indicates the number of samples used in averages when other than the maximum.

Table 25 - Water Quality Data, Cumberland River Basin (cont'd)

Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Manganese (mg/l)	Aluminum (mg/l)	Flow (cfs)
572	Min.		4.2		0.0						
	Max.	7		325.0	34.0	264.0	410.0	21.6	4.8	49.0	5.4
	Avg.			82.7	11.8(5)*	182.0(5)	281.2(5)	5.1	1.5(5)	19.3(5)	2.7(5)
573	Min.		6.7								
	Max.	1		42.0	6.0	64.0	48.0	0.8	-	-	-
	Avg.										
574	Min.		6.3								
	Max.	1		47.0	56.0	56.0	67.0	0.8	-	-	-
	Avg.										
575	Min.		6.9								
	Max.	1		31.0	79.0	116.0	108.0	0.2	-	-	-
	Avg.										
576	Min.		6.4								
	Max.	1		50.0	44.0	60.0	43.0	0.5	-	-	-
	Avg.										
577	Min.		5.1		18.0						
	Max.	7		70.0	96.0	140.0	113.0	1.6	0.7	2.7	420.0
	Avg.			22.4	39.8(6)	110.7(6)	79.0(6)	0.7	0.4(6)	1.0(6)	96.6
578	Min.		4.2		2.0						
	Max.	7		88.0	94.0	256.0	525.0	3.7	3.4	6.0	150.0
	Avg.			40.4	24.2	158.0(6)	181.3(6)	2.5	1.6(6)	2.9(6)	31.5
579	Min.		5.3		4.0						
	Max.	6		64.0	40.0	180.0	96.0	1.2	3.6	2.0	55.0
	Avg.			22.7	22.0(5)	107.2(5)	47.6(5)	0.6	1.0(5)	1.0(5)	21.1(4)
580	Min.		6.7								
	Max.	1		38.0	44.0	56.0	44.0	0.4	-	-	-
	Avg.										
581	Min.		6.3								
	Max.	1		33.0	50.0	88.0	44.0	0.6	-	-	-
	Avg.										

*(5) Indicates the number of samples used in averages when other than the maximum.

Table 25 - Water Quality Data, Cumberland River Basin (cont'd)

Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Manganese (mg/1)	Aluminum (mg/1)	Flow (cfs)
582	Min.		6.5								
	Max.	1		7.0	38.0	84.0	37.0	0.2	-	-	-
	Avg.										
583	Min.		5.9		22.0						
	Max.	5		58.0	30.0	60.0	26.0	2.6	3.3	2.4	20.0
	Avg.			15.8	26.5(4)*	45.0(4)	10.2(4)	1.6	1.0(4)	1.0(4)	7.6
584	Min.		6.4								
	Max.	1		0.0	38.0	52.0	37.0	0.3	-	-	-
	Avg.										
585	Min.		6.2								
	Max.	1		0.0	29.0	44.0	20.0	0.3	-	-	-
	Avg.										
586	Min.		6.3								
	Max.	1		6.0	21.0	28.0	20.0	0.3	-	-	-
	Avg.										
587	Min.		6.3								
	Max.	1		3.0	25.0	40.0	19.0	0.3	-	-	-
	Avg.										
588	Min.		6.4								
	Max.	1		0.0	50.0	60.0	22.0	0.2	-	-	-
	Avg.										
589	Min.		6.7								
	Max.	1		0.0	117.0	128.0	12.0	0.2	-	-	-
	Avg.										
590	Min.		6.9								
	Max.	1		0.0	128.0	140.0	28.0	0.2	-	-	-
	Avg.										
591	Min.		6.8								
	Max.	1		0.0	96.0	96.0	15.0	0.2	-	-	-
	Avg.										

*(4) Indicates the number of samples used in averages when other than the maximum.

Table 25 - Water Quality Data, Cumberland River Basin (cont'd)

Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Manganese (mg/1)	Aluminum (mg/1)	Flow (cfs)
592	Min.		6.5								
	Max.	1		0.0	44.0	64.0	20.0	0.2	-	-	-
	Avg.										
593	Min.		6.4								
	Max.	1		9.0	26.0	92.0	21.0	0.3	-	-	-
	Avg.										
594	Min.		6.7								
	Max.	1		0.0	71.0	156.0	114.0	0.3	-	-	-
	Avg.										
595	Min.		5.9		20.0						
	Max.	6		55.0	52.0	264.0	170.0	18.0	0.7	2.0	29.0
	Avg.			10.5	35.2(5)*	186.4(5)	130.4(5)	3.3	0.5(5)	1.0(5)	10.3(5)
596	Min.		6.1		44.0						
	Max.	6		55.0	140.0	316.0	200.0	14.0	0.8	18.0	35.0
	Avg.			14.3	97.0(5)	257.6(5)	158.6(5)	4.0	0.4(5)	5.9(5)	12.8(5)
597	Min.		4.8		2.0						
	Max.	6		124.0	86.0	272.0	400.0	5.1	0.5	3.8	5.0
	Avg.			24.8	48.2(5)	204.0(5)	180.8(5)	2.6	0.2(5)	1.7(5)	2.4(5)
598	Min.		5.6		12.0						
	Max.	7		52.0	28.0	328.0	420.0	33.0	3.6	26.0	35.0
	Avg.			26.2(6)	19.4	233.3(6)	224.5(6)	9.5	1.9(6)	7.1(6)	12.0
599	Min.		5.5		2.0						
	Max.	6		168.0	30.0	212.0	200.0	3.6	1.9	3.4	24.0
	Avg.			33.0	17.2(5)	113.2(5)	118.0(4)	1.1	1.0(5)	1.8(5)	7.6
600	Min.		5.7		20.0						
	Max.	6		56.0	66.0	368.0	220.0	9.2	1.0	8.1	102.0
	Avg.			13.8	41.4(5)	208.8(5)	133.8(5)	2.5	0.7(5)	2.8(5)	30.6
601	Min.		5.8		38.0						
	Max.	6		125.0	216.0	224.0	305.0	9.5	4.2	5.8	20.0
	Avg.			23.5	125.4(5)	179.2(5)	168.1(5)	5.1	3.4(5)	3.7(5)	5.6

*(5) Indicates the number of samples used in averages when other than the maximum.

Table 25 - Water Quality Data, Cumberland River Basin (cont'd)

Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Manganese (mg/1)	Aluminum (mg/1)	Flow (cfs)
602	Min.		6.2								
	Max.	2		2.0	35.0	100.0	110.0	0.2	-	-	33.0
	Avg.			1.0	35.0(1)*	100.0(1)	110.0(1)	0.2			33.0
603	Min.		4.4		0.0						
	Max.	7		200.0	10.0	156.0	416.0	3.5	4.9	8.5	220.0
	Avg.			41.1	5.5(6)	122.7(6)	145.2(5)	1.1	2.5(6)	2.3(6)	46.6
604	Min.		4.5		0.0						
	Max.	7		156.0	11.0	172.0	220.0	2.0	4.7	5.8	140.0
	Avg.			31.3	5.5(6)	99.3(6)	68.3(6)	0.8	1.3(6)	1.5(6)	33.9
605	Min.		6.3								
	Max.	1		0.0	69.0	136.0	104.0	-	-	-	-
	Avg.										
606	Min.		5.5		10.0						
	Max.	6		88.0	38.0	128.0	140.0	11.0	1.4	22.0	160.0
	Avg.			16.0	26.2(5)	104.8(5)	76.0(5)	2.9	0.7(5)	6.3(5)	74.8
607	Min.		5.8		4.0						
	Max.	5		10.0	182.0	180.0	125.0	1.4	0.4	2.3	8.0
	Avg.			2.5(4)	75.4	137 (4)	94.7(4)	0.6	0.2(4)	1.1(4)	4.3(3)
608	Min.		6.4								
	Max.	1		0.0	32.0	56.0	40.0	0.9	-	-	-
	Avg.										
609	Min.		6.4								
	Max.	1		0.0	32.0	92	78	1.2	-	-	-
	Avg.										
610	Min.		6.5								
	Max.	1		18.0	31.0	56.0	42.0	1.2	-	-	-
	Avg.										
611	Min.		4.9		6.0						
	Max.	6		120.0	38.0	92.0	78.0	1.4	0.8	2.2	31.0
	Avg.			24.2	17.0(5)	67.2(5)	35.0(5)	0.4	0.3(5)	1.4(5)	16.4(5)

*(1) Indicates the number of samples used in averages when other than the maximum.

Table 25 - Water Quality Data, Cumberland River Basin (cont'd)

Map Station No.		No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Manganese (mg/l)	Aluminum (mg/l)	Flow (cfs)
612	Min.		2.8		0.0						
	Max.	7		340.0	87.0	252.0	420.0	16.0	11.2	14.9	14.0
	Avg.			197.2(6)*	12.4	211.8(6)	253.0(6)	8.6	8.7(6)	9.5(6)	3.3
613	Min.		4.3		0.0						
	Max.	7		112.0	14.0	192.0	160.0	1.5	7.6	5.4	11.1
	Avg.			67.5(6)	3.0	156.0(6)	114.6(5)	0.8	6.0(6)	2.3(6)	2.4
614	Min.		5.9		14.0						
	Max.	6		58.0	18.0	80.0	28.0	2.5	1.1	3.6	7.8
	Avg.			14.2	15.6(5)	61.2(5)	21.8(5)	1.1	0.5(5)	1.8(5)	3.9(5)
615	Min.		6.2								
	Max.	1		10.0	10.0	48.0	46.0	-	-	-	-
	Avg.										
616	Min.		6.0		31.0						
	Max.	6		10.0	102.0	164.0	60.0	0.7	0.2	2.1	5.6
	Avg.			4.8	65.8(5)	124.8(5)	47.8(5)	0.2(5)	0.1(4)	1.4(5)	2.7
617	Min.		3.3		0.0						
	Max.	7		250.0	18.0	156.0	140.0	15.0	1.3	9.6	440.0
	Avg.			113.0(6)	3.7	107.3(6)	77.3(6)	7.5	0.7(6)	4.3(6)	75.3
618	Min.		6.8								
	Max.	1		-	-	-	-	-	-	-	-
	Avg.										
619	Min.		6.6								
	Max.	1		6.0	44.0	64.0	36.0	0.2	-	-	-
	Avg.										
628	Min.		6.8								
	Max.	1		0.0	52.0	64.0	20.0	0.2	-	-	-
	Avg.										
629	Min.		7.5								
	Max.	1		0.0	129.0	220.0	53.0	0.2	-	-	-
	Avg.										

*(6) Indicates the number of samples used in averages when other than the maximum.

Table 25 - Water Quality Data, Cumberland River Basin (cont'd)

Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Manganese (mg/1)	Aluminum (mg/1)	Flow (cfs)
630	Min.		7.6								
	Max.	1		0.0	145.0	168.0	12.0	0.2	-	-	-
	Avg.										
631	Min.		6.5								
	Max.	1		44.0	38.0	60.0	22.0	0.2	-	-	-
	Avg.										
632	Min.		6.9								
	Max.	1		8.0	37.0	60.0	13.0	0.2	-	-	-
	Avg.										
633	Min.		8.2								
	Max.	1		0.0	78.0	76.0	40.0	0.2	-	-	-
	Avg.										
634	Min.		7.2								
	Max.	1		0.0	76.0	88.0	22.0	0.5	-	-	1.2
	Avg.										
635	Min.		2.9		0.0						
	Max.	7		780.0	0.0	448.0	530.0	44.0	10.6	78.0	6.0
	Avg.			353.1	0.0	290.0(6)*	260.0(6)	26.1	8.5(6)	28.7(6)	1.1
636	Min.		3.2		0.0						
	Max.	7		420.0	0.0	204.0	512.0	34.0	9.1	7.8	11.1
	Avg.			141.1	0.0	133.3(6)	188.2(6)	11.3	5.9(6)	3.6(6)	2.1
637	Min.		5.8		12.0						
	Max.	7		165.0	48.0	96.0	20.0	3.0	0.5	2.4	160.0
	Avg.			41.8	30.8(6)	52.7(6)	7.3(6)	1.1	0.2(6)	1.5(6)	33.4
638	Min.		4.3		2.0						
	Max.	7		125.0	8.0	160.0	106.0	1.0	1.4	3.8	40.0
	Avg.			35.1	4.0(6)	97.3(6)	66.2(6)	0.3	1.0(6)	1.0(6)	9.2(6)
639	Min.		5.8		12.0						
	Max.	6		205.0	38.0	100.0	140.0	2.5	0.2	3.8	540.0
	Avg.			36.2	23.6(5)	95.2(5)	80.4(5)	1.1	0.2(5)	1.6(5)	186.8

***(6) Indicates the number of samples used in averages when other than the maximum.**

Table 25 - Water Quality Data, Cumberland River Basin (cont'd)

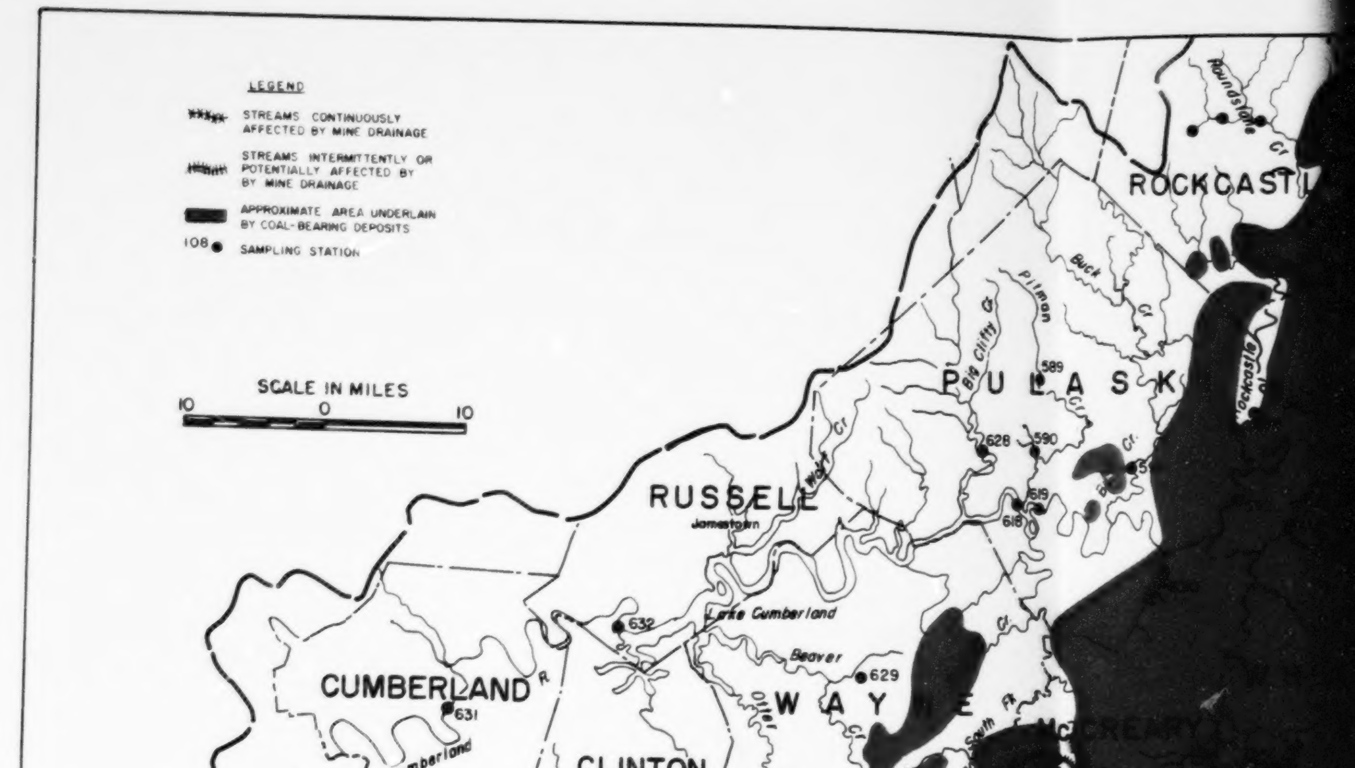
Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Manganese (mg/1)	Aluminum (mg/1)	Flow (cfs)
640	Min.		6.2		1.0						
	Max.	5		132.0	26.0	72.0	140.0	6.9	1.4	12.1	17.0
	Avg.			43.7(4)*	13.6	61.0(4)	67.0(4)	3.0	0.6(4)	6.8(4)	9.6
641	Min.		6.5		10.0						
	Max.	6		64.0	28.0	68.0	160.0	1.8	0.5	2.4	13.0
	Avg.			19.5	20.0(5)	44.0(5)	43.0(5)	1.0	0.2(5)	1.7(5)	3.6
642	Min.		5.5		12.0						
	Max.	5		180.0	21.0	64.0	146.0	1.5	0.2	2.8	5.4
	Avg.			38.4	15.7(4)	43.0(4)	43.2(4)	0.9	0.1(4)	1.3(4)	1.6(4)
643	Min.		4.3		0.0						
	Max.	7		268.0	24.0	152.0	322.0	1.8	1.3	7.3	1030.0
	Avg.			47.6	11.3(6)	112.0(6)	104.7(6)	0.6	0.6(6)	2.6(6)	242.6
644	Min.		6.0		92.0						
	Max.	6		9.0	122.0	144.0	140.0	0.8	0.2	2.9	20.0
	Avg.			4.3	111.5(4)	132.0(5)	31.4(5)	0.5(5)	0.1(5)	1.6(4)	5.3
645	Min.		6.1		82.0						
	Max.	6		4.0	128.0	144.0	170.0	1.0	0.2	2.5	42.0
	Avg.			1.3	107.4(5)	128.4(5)	61.0	0.4	0.1(5)	1.3(5)	21.0
646	Min.		2.5								
	Max.	7		1570.0	0.0	500.0	1300.0	77.0	10.5	69.0	12.3
	Avg.			786.1		365.5(6)	765.3(6)	52.0(6)	6.6(5)	39.4(5)	2.7
647	Min.		2.4		0.0						
	Max.	7		1920.0	0.0	400.0	1200.0	172.0	9.0	68.0	35.0
	Avg.			974.6	0.0	260.7(6)	768.0(6)	99.8	6.4(6)	48.2(6)	6.2
648	Min.		2.7								
	Max.	6		1400.0	0.0	320.0	1210.0	149.0	8.7	56.0	103.0
	Avg.			740.0		251.0	574.7	72.7	6.0	31.0	45.6(5)
649	Min.		3.2								
	Max.	5		144.0	0.0	100.0	95.0	7.4	1.0	3.5	100.0
	Avg.			96.8		49.2	46.0	3.5	0.4	2.3(4)	37.1

*(4) Indicates the number of samples used in averages when other than the maximum.

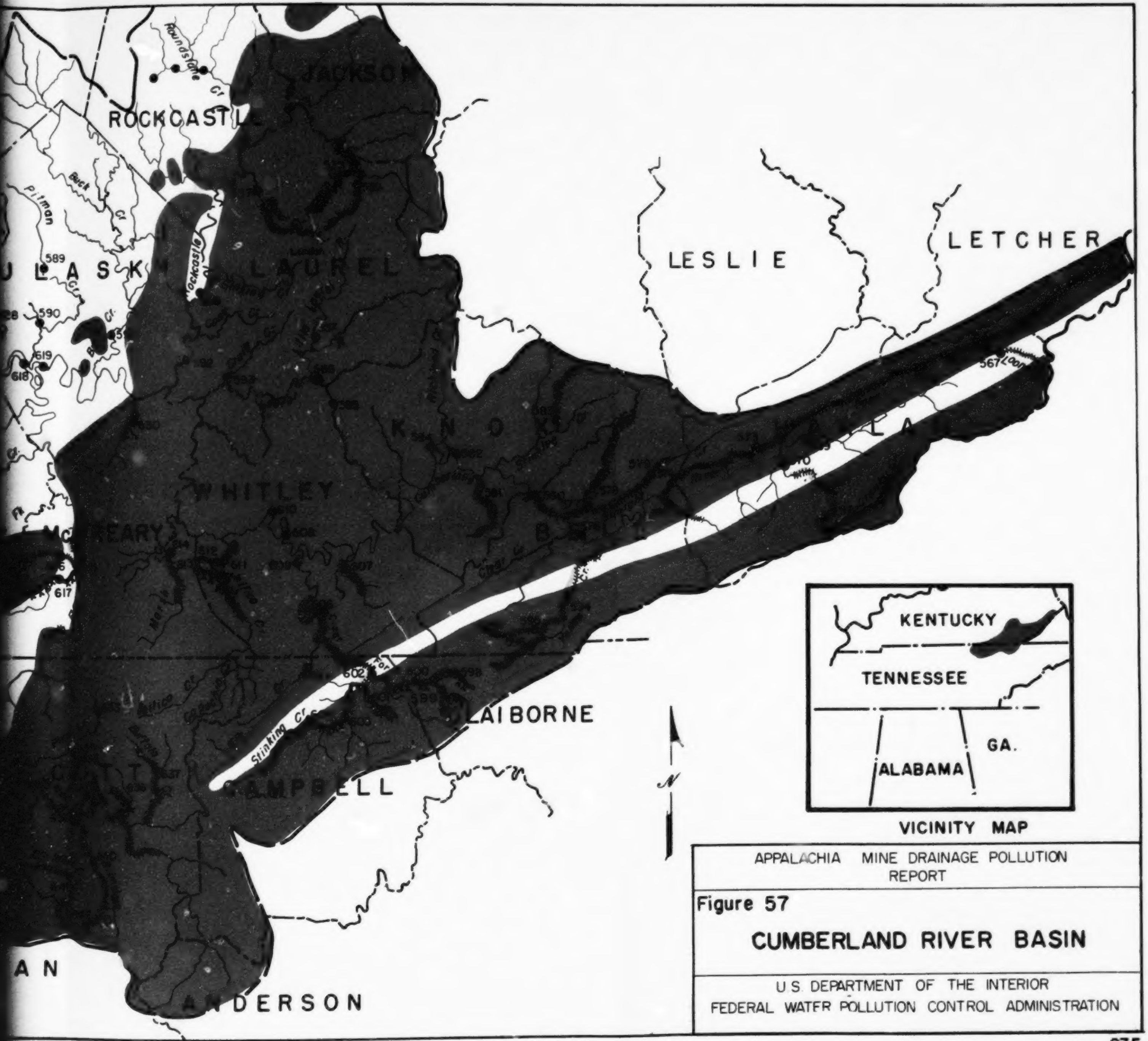
Table 25 - Water Quality Data, Cumberland River Basin (cont'd)

Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Manganese (mg/1)	Aluminum (mg/1)	Flow (cfs)
650	Min.		3.3		0.0						
	Max.	5		156.0	8.0	230.0	195.0	12.3	1.6	3.8	30.0
	Avg.			68.0	2.6	79.0	55.5	5.6(4)*	0.6(4)	2.1(4)	11.4
651	Min.		2.3								
	Max.	4		7200.00	0.0	420.0	5500.0	1700.0	6.7	78.0	2.1
	Avg.			3677.0		290.0	2420.0	750.0	3.8	70.2	0.9(3)
652	Min.		7.2								
	Max.	1		7.0	100.0	124.0	22.0	0.8	-	-	-
	Avg.										
653	Min.		7.2								
	Max.	1		0.0	119.0	152.0	16.0	2.0	-	-	-
	Avg.										
654	Min.		7.0								
	Max.	1		0.0	105.0	112.0	10.0	29.0	-	-	-
	Avg.										
655	Min.		6.9								
	Max.	1		0.0	110.0	128.0	10.0	0.2	-	-	-
	Avg.										
656	Min.		6.3								
	Max.	1		0.0	111.0	124.0	11.0	0.2	-	-	116.0
	Avg.										
657	Min.		7.1								
	Max.	1		0.0	93.0	108.0	4.0	0.4	-	-	-
	Avg.										
658	Min.		7.4								
	Max.	1		0.0	94.0	96.0	3.0	0.2	-	-	-
	Avg.										
659	Min.		7.2								
	Max.	1		0.0	120.0	128.0	16.0	0.5	-	-	-
	Avg.										
660	Min.		6.8								
	Max.	1		0.0	95.0	104.0	110.0	0.2	-	-	306.0
	Avg.										

*(4) Indicates the number of samples used in averages when other than the maximum.


LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
108 SAMPLING STATION
SCALE IN MILES
10
0
10
ROCKCAST
Roundstone Cr.
Buck Cr.
Pitman Cr.
Big Clifty Cr.
Rockcastle
PULASK
589
628
590
619
618
RUSSELL
Jamestown
Wolf Cr.
Lake Cumberland
632
Beaver
629
CUMBERLAND
631
R.
Cumberland
Otter Cr.
WAYNE
South Fk.
Little
617
MCCREARY
CLINTON
Spring Cr.
CLAY
PICKE
Dale Hollow Reservoir
Wolf River
643
Obey R.
JACKSON
OVERTON
64
6
West Fork
MORGAN
NDE

A


JACKSON
ROCKCASTLE
LAUREL
PULASKI
LESLIE
LETCHER
KNOX
BELL
WHITLEY
McCREARY
CLAIBORNE
CAMPBELL
ANDERSON
Roundstone Cr.
Rockcastle
Buck Cr.
Pitman
Stinking Cr.
589
590
619
618
617
602
567
KENTUCKY
TENNESSEE
ALABAMA
GA.
VICINITY MAP
N

APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 57

CUMBERLAND RIVER BASIN

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

B

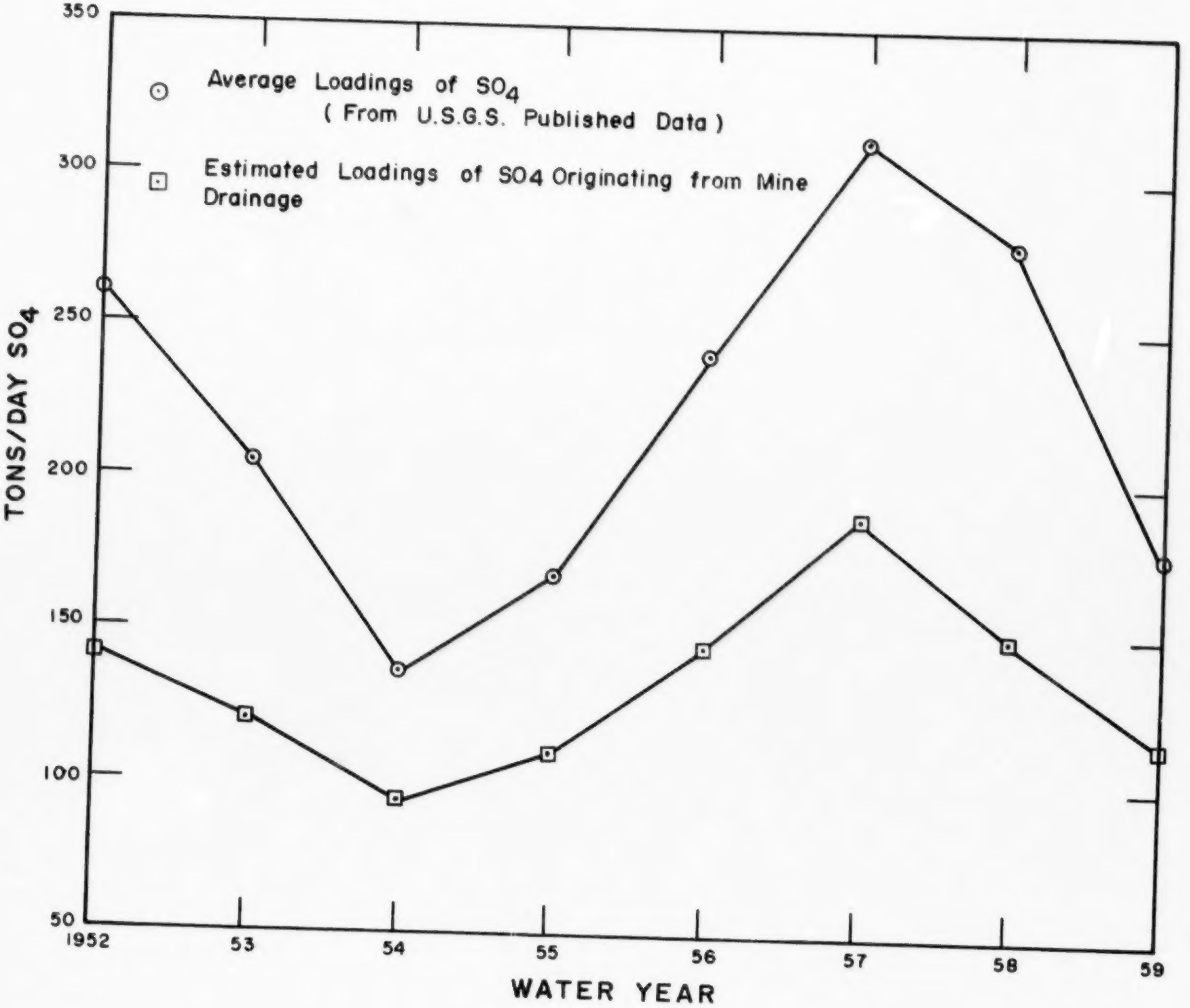


Figure 58. Average loads of total sulfate and sulfate considered to originate from coal mine drainage carried by the Cumberland River at Williamsburg, Kentucky.

Preceding page blank

Tennessee and Black Warrior River Basins

Description

The Tennessee River is formed by the Holston and French Broad Rivers which join just above Knoxville, Tennessee. From this point, the Tennessee River, flows 650 miles through Tennessee, Alabama, and Mississippi to its confluence with the Ohio River. The Tennessee River basin has a total drainage area of 40,900 square miles, about 23,000 square miles of which is within Appalachia.

Physiographic features differ significantly within the Tennessee basin, ranging from the mountainous Blue Ridge physiographic region on the east to the flat-lying Coastal Plain region on the west. Coal reserves lie mainly within the Appalachian Plateaus region, which is underlain by nearly flat-lying sandstones, shales and coals of Pennsylvanian and Mississippian age.

The coal reserves of Tennessee are contained in Pottsville series rocks of Lower Pennsylvanian age. Pennsylvanian rocks in Tennessee consist almost entirely of sandstone, shale and conglomerate, with coal beds and thin limestones comprising a small percentage of the total. Twenty-two Tennessee counties contain coal reserves, fifteen of which are wholly or in part in the Tennessee River basin (Fig. 1). The total recoverable coal reserve in Tennessee is estimated to be about 1 billion tons (Luther, 1959). Commercial coal mining began in Tennessee in the 1830's. Peak production was reached in 1956, when 9 million tons were mined.

Some coal mining is done in the upper portion of the Black Warrior River basin, which lies immediately to the south of the Tennessee watershed in northern Alabama.

The Warrior, Cahaba, Coosa, and Plateau coal fields of northern Alabama contain large reserves of bituminous coal in beds of the Pottsville Formation of Pennsylvanian age. (Culbertson, 1964). Total minable coal reserve in these fields is estimated to be about 13.7 billion tons. Counties with important coal reserves are Jefferson, Tuscaloosa, Walker, Bibb, Shelby, and St. Clair. Jefferson, Tuscaloosa, and Walker Counties together contain 77 percent of the total reserves. Coal has been commercially mined in Alabama since 1832. Peak production was 21.5 million tons in 1926. Most of the production has been from Jefferson and Walker Counties, and it is these Counties in which mine drainage pollution occurs.

Preceding page blank

Mine Drainage Sources and Their Effect on Stream Quality

Mine drainage causes pollution of streams in the upper Tennessee River and Black Warrior River basins, but the problem is small in magnitude in this area as compared to some other Appalachian Region basins.

Surface mining of coal has left 18,600 acres of disturbed unreclaimed land in the Tennessee and Black Warrior basins. The number of underground and surface mine drainage sources is not known.

Stream quality data indicate that more than 20 tons/day of unneutralized mine drainage acidity is carried by streams in the area. However, this acidity is rapidly neutralized by natural sources of alkalinity and pollution effects are, therefore, not generally observable very far from the source. It is estimated that at least 150 miles of streams are significantly polluted by mine drainage, most of them only periodically. Streams found to be significantly polluted are listed in Table 26 and their locations are shown in Figures 59, 60, and 61. Data in Table 27 show the quality of these streams at the time of study. In addition to the streams that are presently known to be polluted, streams where mine drainage pollution may be significant are shown in Figures 60, 61, and 62.

Table 26 - Streams in the Upper Tennessee River Basin Found to be Significantly Polluted by Mine Drainage

Map Station Number	Stream	County
1	Big Creek	Tazewell, Va.
2	Coal Creek	Tazewell, Va.
10	Russell Creek	Wise, Va.
11, 17	Guest River	Wise, Va.
———	Powell River	Wise, Va.
18	Glade Creek	Wise, Va.
———	Callahan Creek	Wise, Va.
27, 28	Jones Creek	Lee, Va.
29	Reeds Creek	Lee, Va.
———	N. Fork Powell River	Lee, Va.
31	Big Creek	Anderson, Tenn.
32	Cove Creek	Anderson, Tenn.
38	Indian Creek	Morgan, Tenn.
40	Little Emory River	Morgan, Tenn.
41	Crooked Fork	Morgan, Tenn.
42	Emory River	Morgan, Tenn.
43	Mill Creek	Morgan, Tenn.
51	Rock Creek	Cumberland, Tenn.
52	Big Possum	Cumberland, Tenn.
53	Woodcock Creek	Sequatchie, Tenn.

Chemical evidence of coal mine drainage pollution in streams in the Virginia portion of the Tennessee River basin (Stas. 1-29, Fig. 60) is expressed by reduction in natural alkalinity levels and by above normal concentrations of mine drainage indicators. Generally, only iron and manganese are present in excessive concentrations as mine drainage indicators. High acidity concentrations and low pH values are not observed, because stream alkalinity and the limestone and dolomite beds over which the streams flow rapidly neutralize any acidity that enters the surface waters. Reeds Creek (Sta. 29) was acid when examined and had a pH of 4.2. Pollution of Reeds Creek is caused by extensive surface and underground mining.

In the Tennessee portion of the Tennessee River basin (Stas. 31-55, Figs. 60 and 61), Mill Creek, Big Possum Creek, and Woodcock Creek were found to have pH values below 5.0. No other stream had pH values of less than 6.2 at the time of examination. Other significantly polluted streams, as listed in Table 26, had excessive concentrations of mine drainage indicators and/or the natural alkalinity was depleted by reaction with mine drainage acidity.

The water quality data in Table 27 do not necessarily reflect the severity of mine drainage pollution in some streams. The Tennessee Game and Fish Commission has reported, for example, that Beech Grove Fork (Sta. 34) and Poplar Creek (Sta. 37) are polluted during periods of high runoff, when mine drainage pollutants are flushed into these streams. In addition, what may appear to be minor mine drainage pollution may actually represent conditions that significantly affect the biological life in some streams. The Tennessee Game and Fish Commission reports, for example, that in 1958 Crooked Fork (Sta. 41, Fig. 60) was an ideal muskellunge habitat, but that it is no longer suitable for this purpose due to recent surface mining operations. The chemical analyses in Table 27 for this stream show a depletion in alkalinity and slightly high concentrations of other indicators, but no evidence of severe pollution at the time of sampling.

Through a biological examination of streams in Jefferson and Walker Counties, Alabama, in the Black Warrior River basin (McClellan and Zoellner, 1966), it has been determined that Lost Creek, Mill Creek and Cane Creek (Fig. 62) are likely to be polluted by mine drainage. The Alabama Geological Survey (written communication) has reported that the Black Branch, Spring Creek, Cane Creek, Shelton Branch, Hanna Mill, Daniel Creek and tributaries to Short Creek, Spring Creek, and Black Branch in the Black Warrior River basin (Fig. 62), were found to have pH values ranging from 3.5 to 4.5. Mine drainage pollution in this area is from active or inactive surface mines. Luxapallila Creek is also reportedly polluted by mine drainage (U. S. Dept. of Agriculture, 1966).

Table 27 - Water Quality Data, Tennessee River Basin

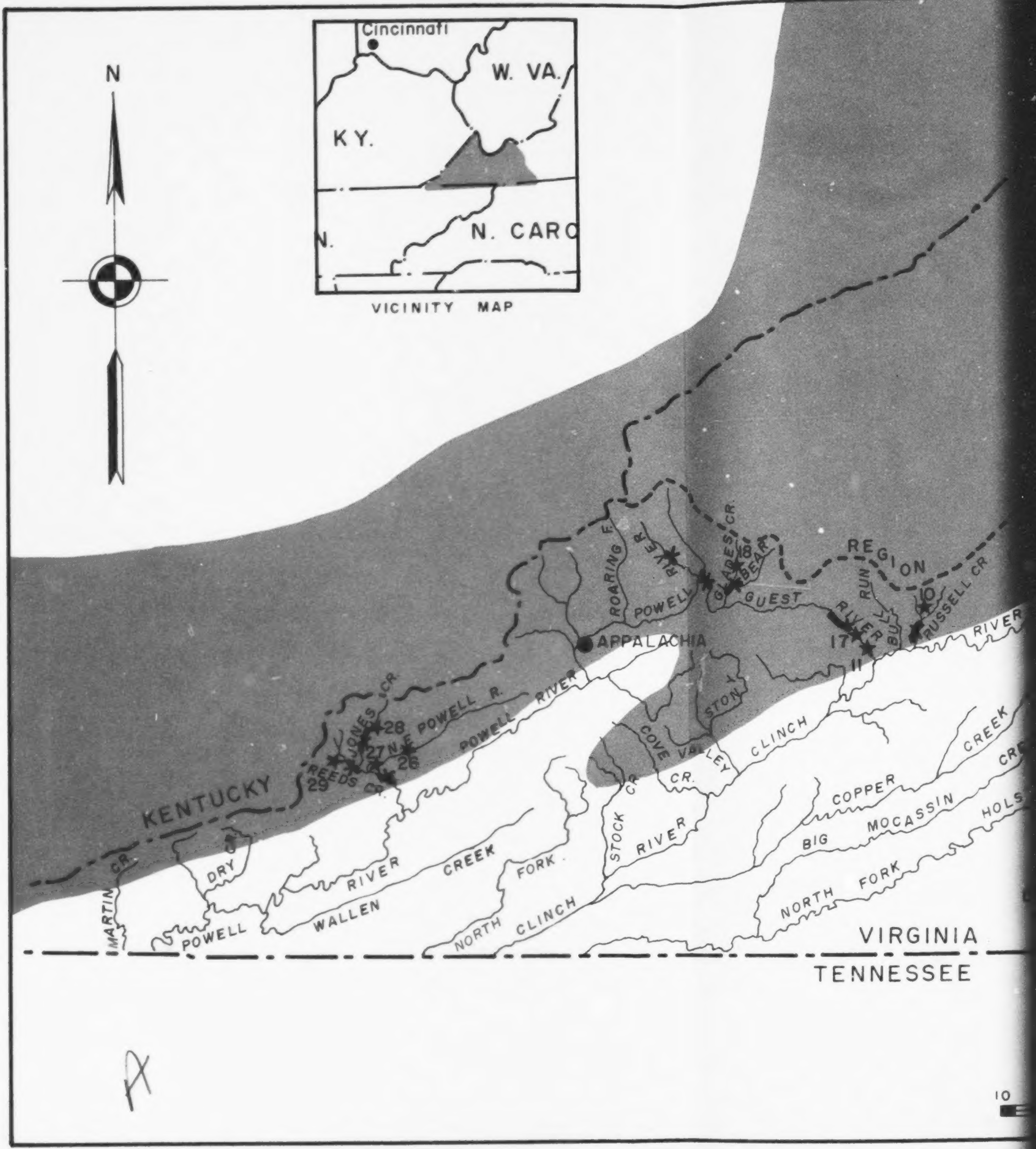
Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Manganese (mg/1)	Specific Conductance (Micro-mho)	Flow (cfs)
	Min.		6.6								
1	Max.	2		10.0	11.0	44.0	13.0	0.9	0.2	115.0	21.1
	Avg.			6.0	9.5	44.0	14.5	0.9	0.1	112.5	16.0
	Min.		7.0								
2	Max.	2		4.0	31.0	88.0	31.0	2.4	0.4	231.0	8.7
	Avg.			2.0	30.5	84.0	29.5	2.0	0.4	216.5	6.4
	Min.		7.6								
4	Max.	1									
	Avg.			0.0	88.0	120.0	3.0	0.2	0.0	225.0	279
	Min.		7.5								
6	Max.	2		0	116.0	144.0	4.0	0.4	0.05	247.0	890.0
	Avg.			0	108.0	134.0	4.0	0.3	0.025	240.5	660.0
	Min.		6.9								
10	Max.	2		4.0	32.0	152.0	59.0	2.6	0.8	367	6.7
	Avg.			2.0	30.0	134.0	56.0	2.4	0.6	316.5	6.4
	Min.		6.7								
11	Max.	2		2.0	30.0	64.0	22.0	4.4	0.4	171.0	295.0
	Avg.			1.0	23.0	58.0	19.0	2.9	0.3	154.5	248.5
	Min.		6.5								
17	Max.	2		8.0	12.0	68.0	18.0	1.8	0.4	154.0	54.7
	Avg.			4.0	11.0	56.0	18.0	1.5	0.4	140.5	41.1
	Min.		6.3								
18	Max.	2		6.0	14.0	68.0	28.0	0.9	0.8	152.0	
	Avg.			3.5	12.0	64.0	25.0	0.85	0.7	150.0	
	Min.		6.4								
26	Max.	2		6.0	8.0	44.0	6.0	0.4	0.1	58.0	44.8
	Avg.			4.0	8.0	32.0	4.5	0.4	0.05	49.5	43.3
	Min.		5.1								
27	Max.	1									
	Avg.			6.0	1.0	32.0	16.0	1.7	0.2	95	15.2

Table 27 - Water Quality Data, Tennessee River Basin (cont'd)

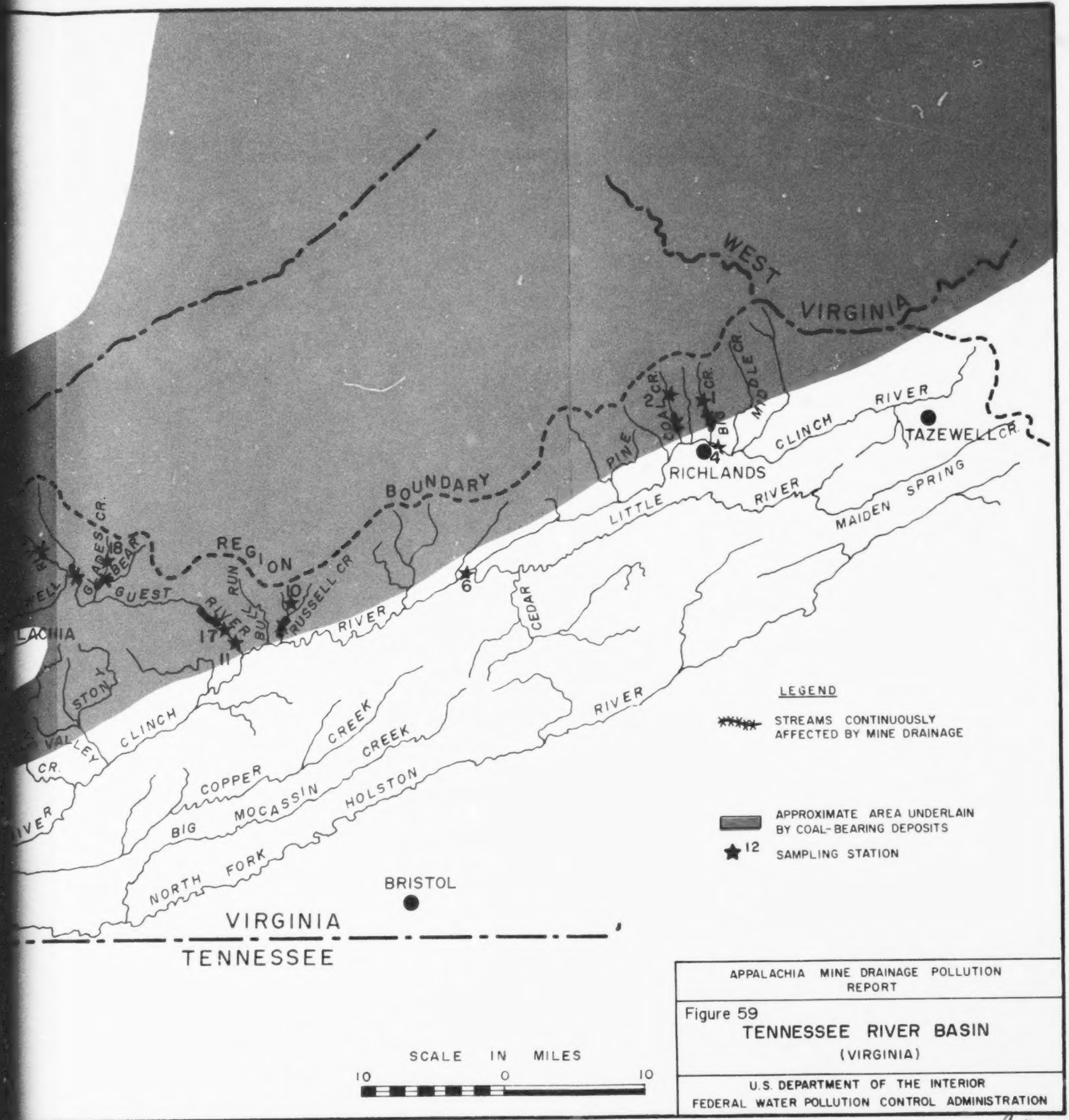
Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Manganese (mg/1)	Specific Conductance	Flow (cfs)
28	Min. Max. Avg.	2	6.7	8.0 5.0	12.0 10.0	80.0 54.0	14.0 12.0	0.5 0.4	0.1 0.1	98.0 86.0	7.1 6.8
29	Min. Max. Avg.	1	4.2	17.0	0.0	40.0	31.0	3.5	0.4	144.0	-
31	Min. Max. Avg.	2	6.7	8 4	12 10	84.0 60.0	16 13	1.3 0.9	0.3 0.3	137.0 120.5	8.8 8.4
32	Min. Max. Avg.	1	6.9	6.0	20.0	88.0	1.3	0.6	0.1	120.0	36.5
34	Min. Max. Avg.	2	7.0	0.0 0.0	32.0 24.0	120.0 74.0	38 22	2.2 1.3	0.3 0.25	217.0 144.0	8.3 6.7
36	Min. Max. Avg.	1	7.4	0	64.0	112.0	65	0.4	0.1	331.0	4.9
37	Min. Max. Avg.	2	6.9	0.0 0.0	46.0 35.0	164.0 128.0	75.0 46.5	1.1 .9	0.5 0.45	313 252	70 40.2
38	Min. Max. Avg.	2	6.6	2.0 1.0	24 21	124.0 80.0	65.0 37.0	0.8 0.7	1.7 0.9	274.0 193.0	8.4 6.7
40	Min. Max. Avg.	2	6.7	2.0 1.0	16.0 12.0	88.0 64.0	43.0 26.0	0.4 0.35	0.5 0.35	202.0 142.5	36.2 -
41	Min. Max. Avg.	2	6.2	4.0 4.0	4.0 4.0	80.0 56.0	41.0 33.0	0.9 0.5	0.8 0.7	186.0 173.0	

Table 27 - Water Quality Data, Tennessee River Basin (cont'd)

Map Station No.		No. of Samples	pH	Acidity (mg/1)	Alkalinity (mg/1)	Hardness (mg/1)	Sulfate (mg/1)	Total Iron (mg/1)	Manganese (mg/1)	Specific Conductance	Flow (cfs)
42	Min.		6.5								
	Max.	1		0	8.0	36.0	2.0	0.2	0.1	58.0	1200.0
	Avg.										
43	Min.		4.9								
	Max.	2		6	2	64.0	24.0	0.5	1.3	117.0	8.7
	Avg.			5	2	48.0	16.0	0.5	.9	87.5	5.35
44	Min.		6.5								
	Max.	1		2.0	8.0	40.0	1.0	0.3	0.1	44.0	1150.0
	Avg.										
46	Min.		6.6								
	Max.	2		3.0	10.0	48.0	16.0	1.9	0.2	46.0	6.7
	Avg.			1.5	8.0	24.0	10.0	1.3	0.15	37.5	-
51	Min.		6.2								
	Max.	2		6.0	6.0	8.0	4.0	0.5	0.1	38.0	420.0
	Avg.			4.5	5.0	8.0	2.0	0.4	0.08	28.0	238.6
52	Min.		4.0								
	Max.	2		20.0	0.0	24	13.0	2.2	0.7	94.0	193.0
	Avg.			15.0	0.0	18	9.0	1.3	0.5	73.5	102.9
53	Min.		4.9								
	Max.	2		6.0	2.0	20.0	3.0	0.4	0.2	49.0	153.0
	Avg.			4.0	1.0	14.0	2.5	0.2	0.2	40.5	82.0
54	Min.		6.9								
	Max.	1		0.0	24.0	36.0	3.0	0.4	0.1	78.0	7.3
	Avg.										
55	Min.		6.3								
	Max.	2		4.0	14.0	40.0	7.0	0.4	0.2	87.0	30.4
	Avg.			2.0	11.0	30.0	6.0	0.35	0.15	74.0	17.7
56	Min.		7.1								
	Max.	2		0	36.0	76.0	7.0	0.4	0.1	156	272.0
	Avg.			0	30.0	64.0	4.5	0.3	0.05	128	182.5


Cincinnati
W. VA.
KY.
N. CARO
N.
VICINITY MAP
N
REGION
KENTUCKY
APPALACHIA
ROARING F
POWELL R.
RIVER
GLADES CR.
BEAR
GUEST
RIVER
RUN
BUL
RUSSELL CR
RIVER
18
17
11
10
JONES CR.
N.F. POWELL R.
POWELL RIVER
28
27
26
29
REEDS CR.
STON
COVE VALLEY
CLINCH
CR.
STOCK CR.
RIVER
COPPER CREEK
BIG MOCASSIN CR
HOLS
NORTH FORK
MARTIN CR.
DRY
POWELL RIVER
WALLEN CREEK
NORTH FORK
NORTH CLINCH
VIRGINIA
TENNESSEE
10

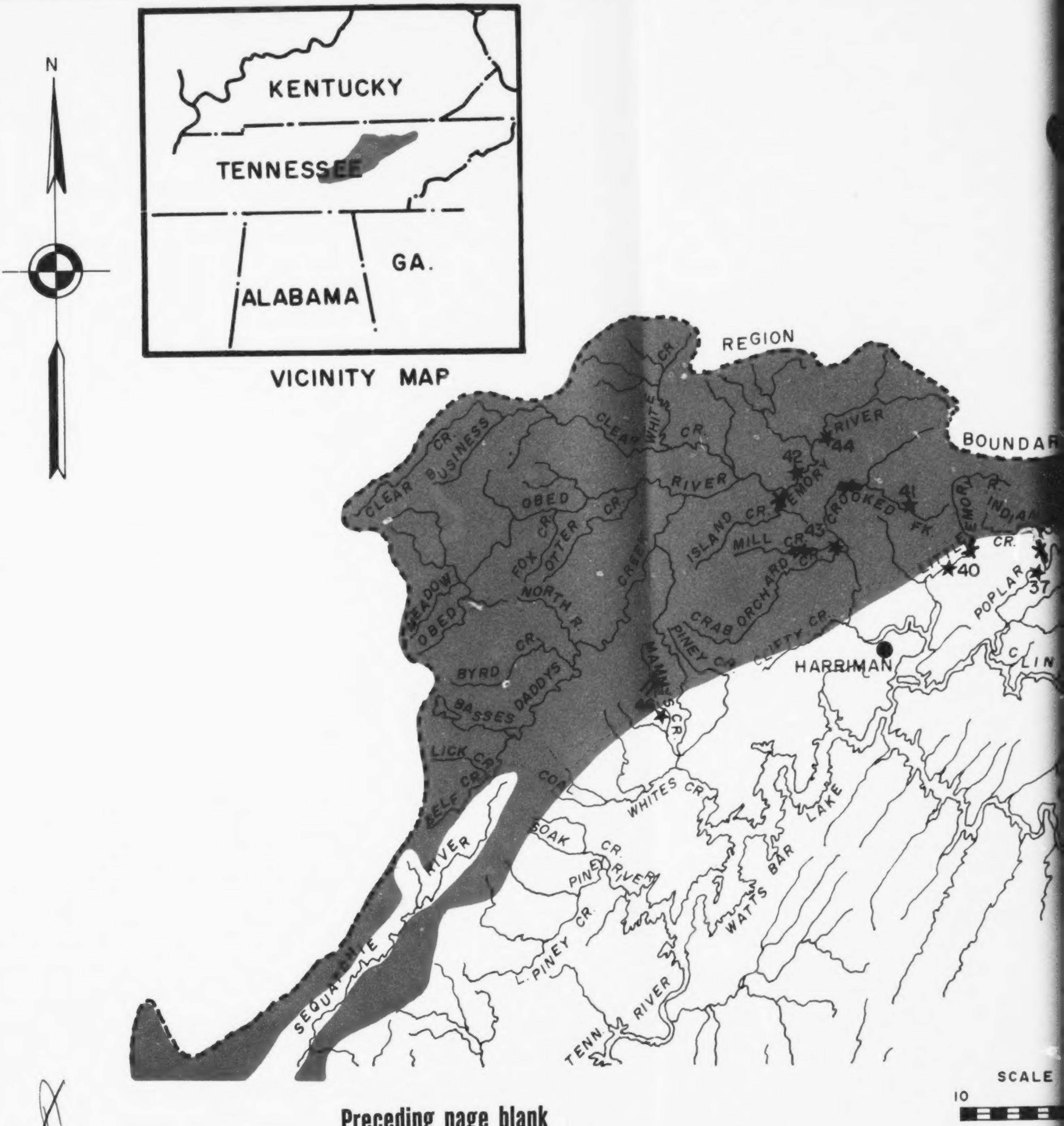
A


WEST VIRGINIA
BOUNDARY
REGION
RICHLANDS
TAZEWELL CR.
CLINCH RIVER
LITTLE RIVER
MAIDEN SPRING
PINE
COAL CR.
BIG CR.
MIDDLE CR.
RUSSELL CR
RUN
BULL
RIVER
GUEST
GLADES CR.
BEAR
WELL
LACHIA
STON
VALLEY CR.
CLINCH
CEDAR
COPPER CREEK
BIG MOCASSIN CREEK
HOLSTON RIVER
NORTH FORK
IVER
BRISTOL
VIRGINIA
TENNESSEE
1
2
4
6
10
11
17
18
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
12 SAMPLING STATION
SCALE IN MILES
10
0
10

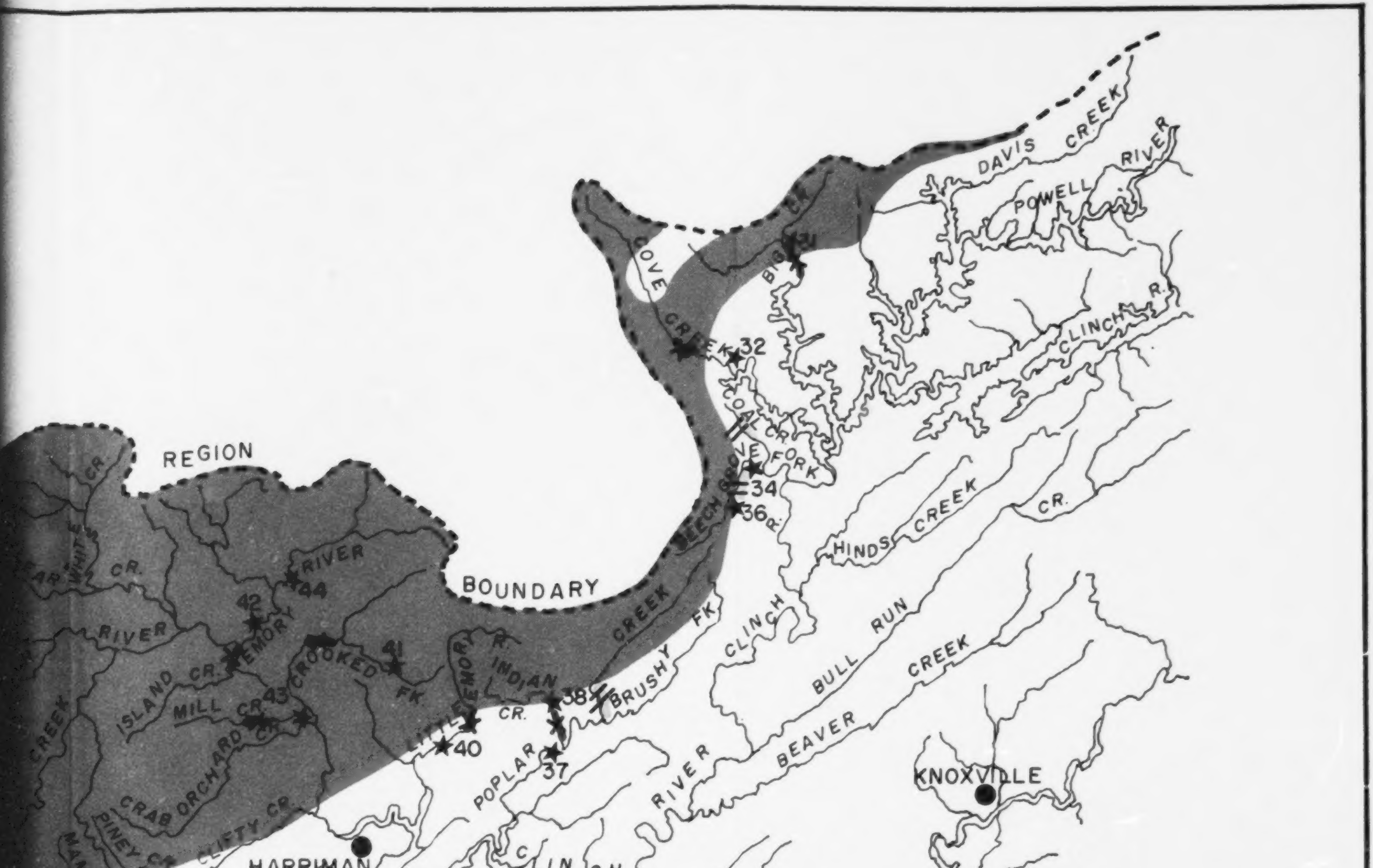
APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 59
TENNESSEE RIVER BASIN
(VIRGINIA)

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION


N
KENTUCKY
TENNESSEE
GA.
ALABAMA
VICINITY MAP
REGION
BOUNDAR
CLEAR CR.
BUSINESS
CLEAR
WHITE CR.
CLEAR CR.
RIVER
44
42
EMORY
41
CROOKED FK.
INDIAN
EMORY R.
CR.
OBED
RIVER
FOX CR.
OTTER CR.
ISLAND CR.
MILL CR.
43
CREEK
NORTH R.
MEADOW
OBED
CRAB ORCHARD CR.
PINEY CR.
CLIFTY CR.
LITTLE
40
37
POPLAR
HARRIMAN
CLIN
BYRD CR.
DADDYS
BASSES
MAMMYS CR.
LICK CR.
SELF CR.
COAL
WHITES CR.
SOAK CR.
PINEY RIVER
RIVER
LAKE
WATTS BAR
L. PINEY CR.
SEQUATCHIE
TENN. RIVER
SCALE
10

Preceding page blank

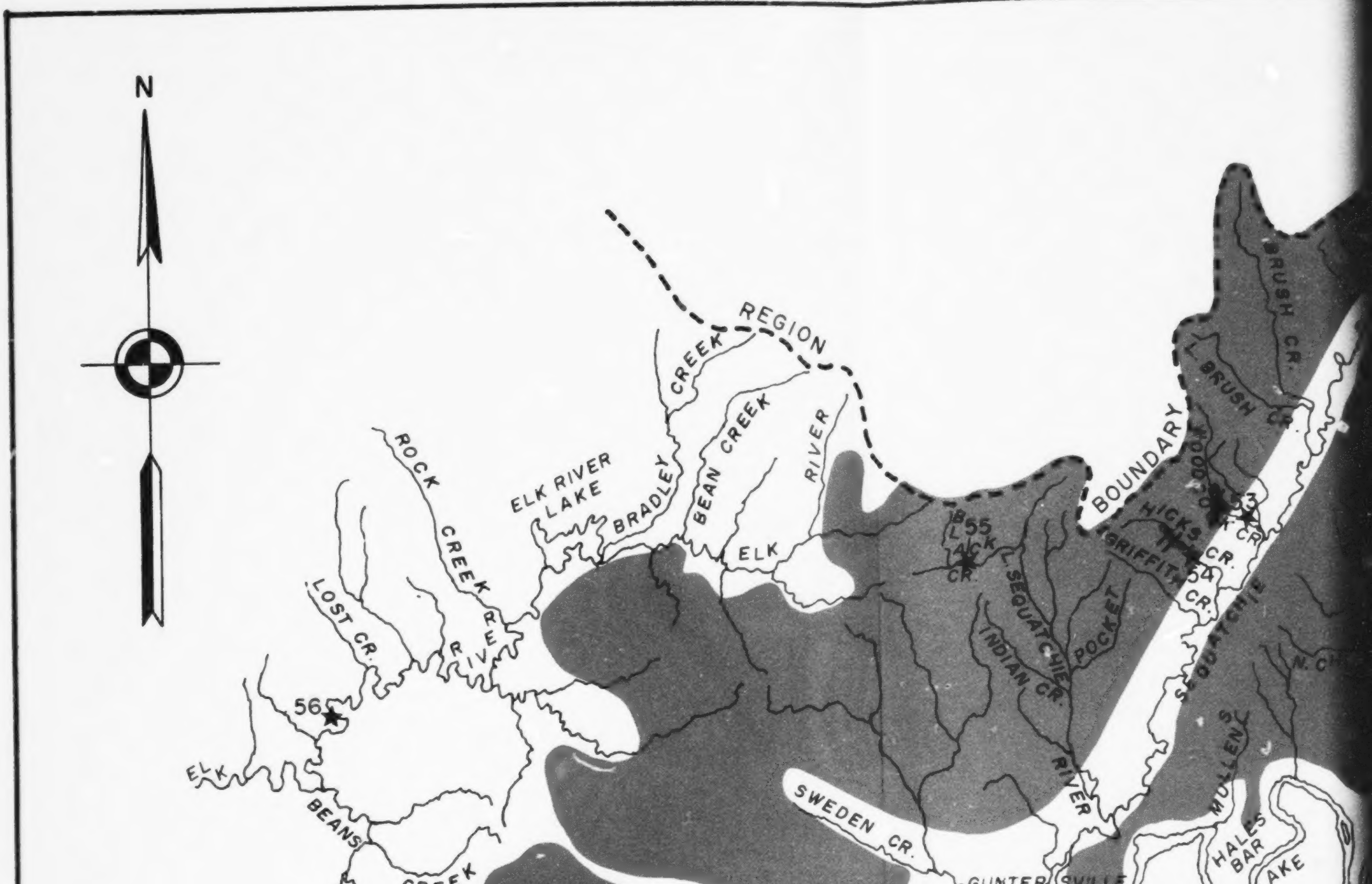

REGION
BOUNDARY
DAVIS CREEK
POWELL RIVER
BIG CR.
COVE CREEK
32
COAL CR.
COVE FORK
34
36
BEECH GROVE
CLINCH R.
HINDS CREEK
CR.
CLINCH RIVER
BULL RUN
BEAVER CREEK
BRUSHY FK
CREEK
INDIAN CR.
38
37
POPLAR
LITTLE EMORY R.
40
KNOXVILLE
WHITE CR.
CR.
RIVER
44
42
EMORY
RIVER
ISLAND CR.
41
CROOKED FK
MILL CR.
43
CRAB ORCHARD CR.
CREEK
PINEY CR.
CLIFTY CR.
MAMMYS CR.
46
HARRIMAN
CLINCH
WHITES CR.
WATTS BAR LAKE
CR.
RIVER
RIVER
LENOIR CITY
TENNESSEE
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
12
SAMPLING STATION
SCALE IN MILES
10
0
10

APPALACHIA MINE DRAINAGE POLLUTION REPORT

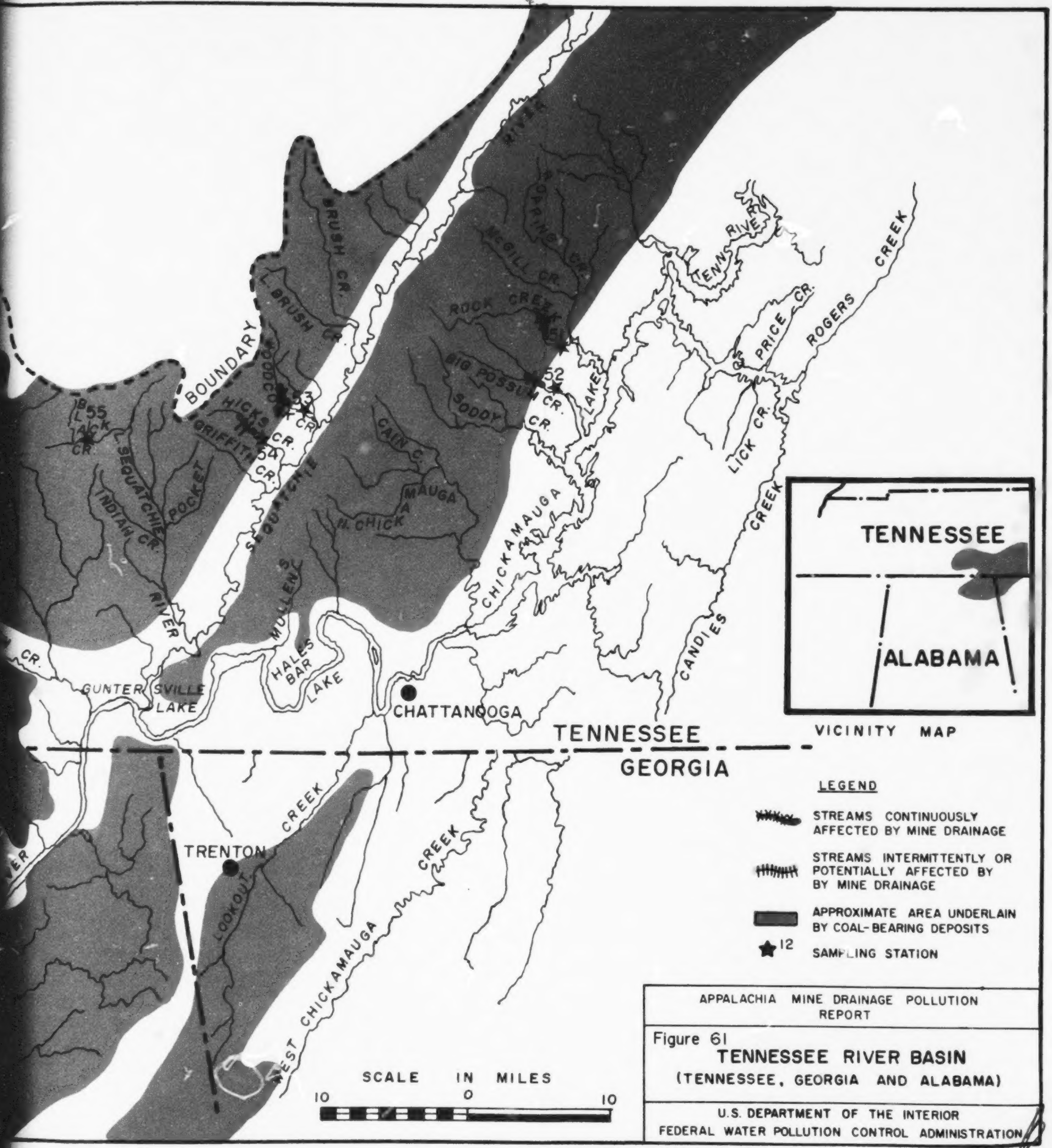
Figure 60
TENNESSEE RIVER BASIN
(TENNESSEE)

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

B


N
REGION
BOUNDARY
CREEK
BEAN CREEK
RIVER
BRADLEY
ELK RIVER LAKE
ROCK CREEK RIVER
LOST CR.
56
ELK
BEANS CREEK
ELK
BLACK CR.
55
L. SEQUATCHIE
INDIAN CR.
POCKET
HICKS CR.
GRIFFITH CR.
54
53
BRUSH CR.
L. BRUSH CR.
SEQUATCHIE
N. CH
MULLENS
RIVER
SWEDEN CR.
GUNTERSVILLE LAKE
HALES BAR LAKE
TENNESSEE
ALABAMA
LITTLE COON
CROW CR.
CR.
BIG COON CR.
MUD CR.
RIVER
TENN.
TRENTON
LOOKOUT CREEK
WEST CHICKAMAUGA
SC
10

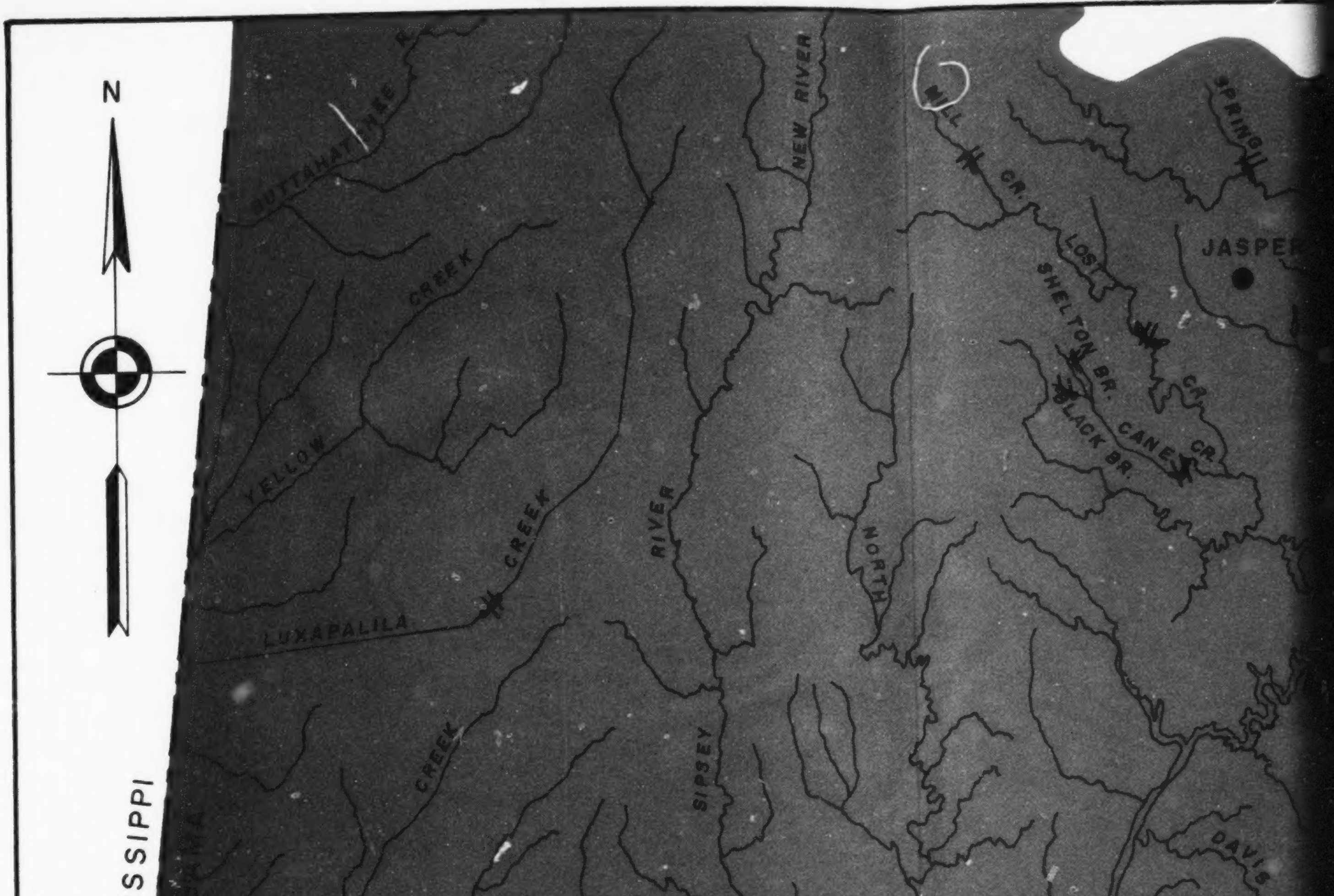
Preceding page blank

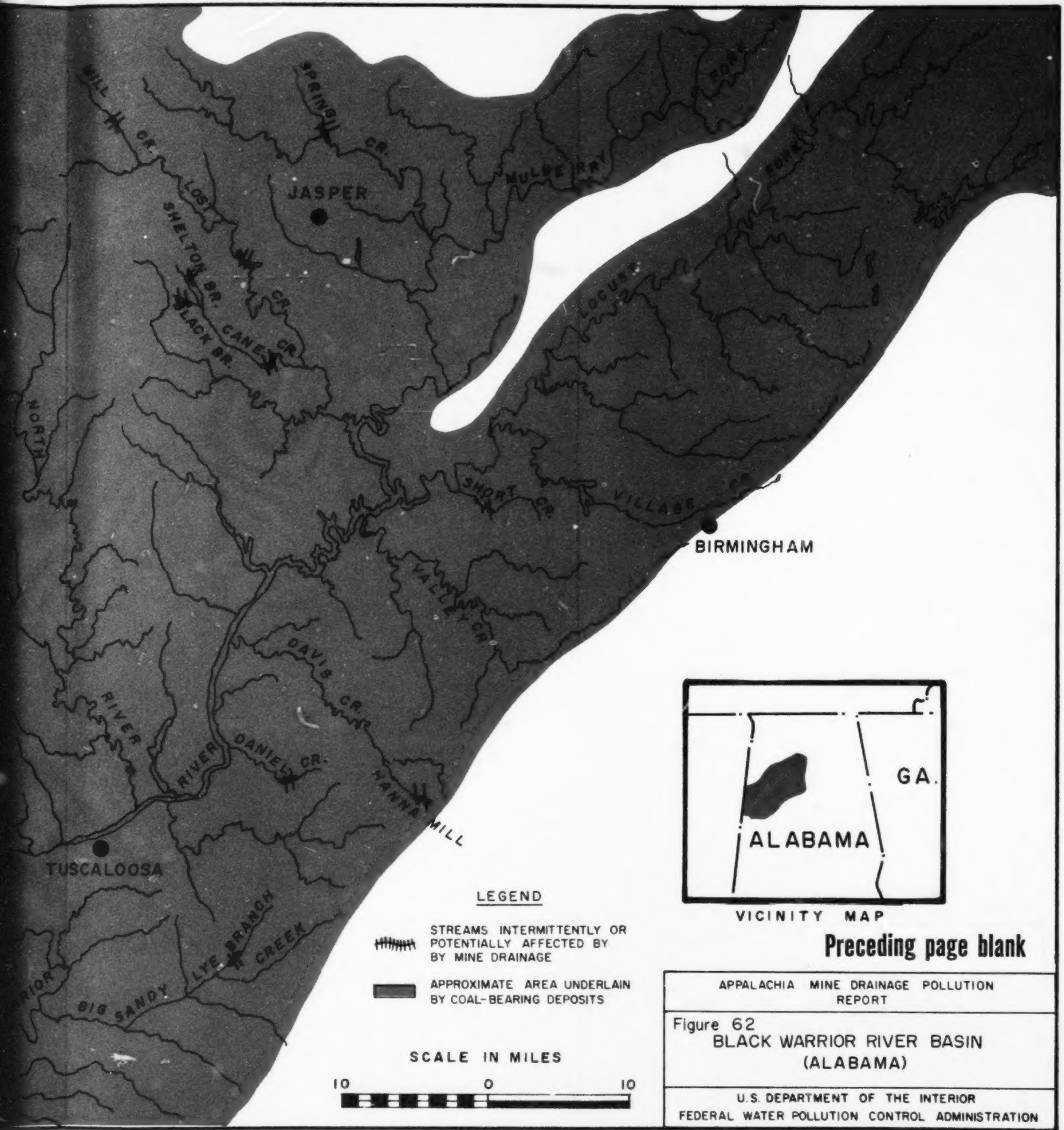

BOUNDARY
BRUSH CR.
L. BRUSH CR.
WOODCOCK CR.
HICKS CR.
GRIFFITH CR.
BLACK CR.
55
54
53
L. SEQUATCHIE
INDIAN CR.
POCKET
SEQUATCHIE
RIVER
RIVER
ROARING CR.
McGILL CR.
ROCK CREEK
BIG POSSUM CR.
SODDY CR.
51
52
CAIN C.
N. CHICKAMAUGA
MULLENS
HALES BAR LAKE
LAKE
CHICKAMAUGA
TENN. RIVER
PRICE CR.
ROGERS CREEK
LICK CR.
CANDIES CREEK
CR.
GUNTERSVILLE LAKE
CHATTANOOGA
TENNESSEE
GEORGIA
TRENTON
LOOKOUT CREEK
WEST CHICKAMAUGA CREEK
RIVER
TENNESSEE
ALABAMA
VICINITY MAP
LEGEND
STREAMS CONTINUOUSLY AFFECTED BY MINE DRAINAGE
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
12 SAMPLING STATION
SCALE IN MILES
10
0
10

APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 61
TENNESSEE RIVER BASIN
(TENNESSEE, GEORGIA AND ALABAMA)

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION


N
MISSISSIPPI
ALABAMA
BUTTAHATCHEE R.
YELLOW
CREEK
CREEK
LUXAPALILA
COAL
FIRE
CREEK
CREEK
CREEK
LUBBUB
SIPSEY
RIVER
RIVER
SIPSEY
RIVER
NEW RIVER
NORTH
RIVER
MILL
CR.
LOST
CR.
SHELTON BR.
BLACK BR.
CANE
CR.
SPRING
JASPER
DAVIS
CR.
DANIEL CR.
RIVER
TUSCALOOSA
WARRIOR
BLACK
BIG SANDY
LYE BRANCH
CREEK
10


MILL CR.
SPRING CR.
MULBERRY
FORK
LOCUST
FORK
JASPER
LOST CR.
SHELTON BR.
BLACK BR.
CANE CR.
NORTH
SHORT CR.
VILLAGE CR.
BIRMINGHAM
VALLEY CR.
DAVIS CR.
RIVER
DANIEL CR.
HANNA MILL
TUSCALOOSA
LYE BRANCH
CREEK
BIG SANDY
RIOR
LEGEND
STREAMS INTERMITTENTLY OR POTENTIALLY AFFECTED BY BY MINE DRAINAGE
APPROXIMATE AREA UNDERLAIN BY COAL-BEARING DEPOSITS
SCALE IN MILES
10
0
10
GA.
ALABAMA
VICINITY MAP

Preceding page blank

APPALACHIA MINE DRAINAGE POLLUTION REPORT

Figure 62
BLACK WARRIOR RIVER BASIN
(ALABAMA)

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

B

PROJECTED CONDITIONS

The present problem of mine drainage pollution in Appalachia can be discussed in terms of various parameters such as miles of polluted streams, concentrations of mine drainage indicators in the waters at selected points on streams, or loads of mine drainage indicators carried by streams at selected points. The same parameters could be used to compare the future situation with that of today, but only a few measurements appear useful for comparing conditions in the past with those of today.

Acidity concentrations or loads have generally been used to characterize the problem and, for example, it is estimated in this report that at least 6,000 tons/day of unneutralized acidity enters streams in Appalachia. Acidity is, however, a somewhat difficult and unreliable indicator to use in many cases for several reasons. Three such reasons are, first, that different laboratory methods are used that may give greatly different results, second, that there is no way of adjusting such results to make them comparable, and third, that acidity is often not measurable very far from where it enters a stream, because it is neutralized by natural sources of alkalinity.

For the above reasons analyses were made of average sulfate loads at locations on major streams as listed in Table 28.

The total sulfate loads shown in the figures listed in Table 28 were computed by water year as time and discharge weighed daily averages. Data were obtained from the U. S. Geological Survey Water Supply Papers entitled "Surface Water Quality in the United States," which have been published annually since 1944.

Table 28 - Listing of Streams for Which Average Yearly Sulfate Loads are Given

Stream	Figure Number	Page
1. Susquehanna River at Danville, Pa.	5	51
2. Schuylkill River at Berne, Pa.	4	50
3. Lehigh River at Catasauqua, Pa.	3	49
4. West Branch Suseuqhanna River at Lock Haven, Pa.	26	95
5. Allegheny River at Kittanning, Pa.	38	133
6. Kiskiminetas River at Vandergrift, Pa.	39	134
7. Monongahela River at Charleroi	41	151

Preceding page blank

Table 28 (cont'd)

Stream	Figure Number	Page
8. Youghiogheny River at Sutersville, Pa.	42	152
9. Hocking River at Athens, Ohio	46	173
10. Big Sandy River at Catlettsburg, Ky.	52	205
11. Cumberland River at Williamsburg, Ky.	58	247

Sulfate was selected as an indicator because:

1. One molecular weight of sulfate is formed for each molecular weight of sulfuric acid. The weight ratio is also nearly identical, being 0.98 tons of sulfate per ton of sulfuric acid.
2. The sulfate does not disappear when the acidity is neutralized.
3. Calcium sulfate, the usual form, is soluble in the concentrations usually encountered.
4. The analysis for sulfate is reliable.
5. Many sulfate analyses are available.

Available acidity loadings are shown in Figures 4, 26, 39, and 41, for comparison with the sulfate data. The trends in acidity loads seem generally to be reflected by trends in sulfate loads.

A problem in using sulfate as an indicator of mine drainage is an interference from industrial wastes that contain sulfates. This problem prevented use of U. S. Geological Survey data from the Beaver River and Kanawha River basins. In addition, sulfate occurs naturally in Appalachian streams. Therefore, in order to indicate the magnitude of sulfate originating from mine drainage, measured sulfate concentrations were reduced by an average of 20 mg/l. An average sulfate concentration of 20 mg/l was determined to be a representative natural level in several streams not affected by mine drainage. Natural concentrations may be lower than 20 mg/l in some streams, but were not observed to be higher than this in Appalachian streams that are unaffected by drainage from coal areas. In general, it was observed that many of the extreme fluctuations shown in the figures listed in Table 28 resulted from hydrologic variations. Years of high precipitation resulted in low average sulfate concentrations, but high stream loads. In dry years, concentrations were high, but loads low. This type of variation could apparently result in load differences of over 50 percent in two succeeding years.

Data in Figure 5 show that between 1250 and 2000 tons/day of sulfate originated from mine drainage in the Susquehanna River basin portion of the Anthracite region during the period 1946 to 1963. The average amount was about 1500 tons/day. Sulfate loads at the end of this 17 year period were not greatly different than at the beginning.

These data may be useful in projecting the pollution potential from mining in the Anthracite region. Anthracite production was at its lowest level during this century in 1962 (17 million tons/year). Coal production for the Susquehanna basin portion of the Anthracite area is projected as being about the same in 1980 as in 1962. Based on these few data, it might be expected that mine drainage pollution loads in the Susquehanna portion of the Anthracite area will remain in the same order of magnitude in 1980 as today, unless abatement measures are applied.

Sulfate loads in the Lehigh River (Fig. 3) remained about the same during 1945-1952. No recent data are available. Sulfate loads in the Schuylkill River (Fig. 4) were relatively high during 1951-1953 but were less at the end of the period 1948-1959 than in the beginning. Annual anthracite production in 1980 is projected to be perhaps half that during the period 1946-1948. Based on this projection, mine drainage pollution loads in 1980 will probably not exceed those shown in Figures 3 and 4, but substantial improvement is not anticipated without an abatement program.

Sulfate loads carried by the West Branch of the Susquehanna at Lock Haven, Pennsylvania (Fig. 26) appear to be an excellent indicator of the amount of mine drainage pollution discharged to this stream during 1946-1963. Variation in loads was not extreme during this period and loads at the end of the period were essentially the same as in the beginning. Coal production during this period has been relatively stable, averaging about 9 million tons/year. Projected production in 1980 is about 8.5 million tons (Wessel, and others, 1964). It can reasonably be concluded on the basis of past and present pollution loads and past, present, and projected mining activity that mine drainage pollution in the West Branch of the Susquehanna River will continue at the present level until 1980 unless abatement measures are applied.

Sulfate load data for the Allegheny River above the Kiskiminetas River are given in Figure 38, and sulfate load data for the Kiskiminetas River are given in Figure 39. Data in both of these figures appear to indicate some trend toward an overall decrease in pollution loads in the Allegheny basin, but the combined load of sulfate attributed to mine drainage in the Allegheny basin was, within the limits of error, the same in 1962 (1,960 tons/day) as in 1947 (1,900 tons/day).

Chemical data are available for the Allegheny River from as far back as about 1910 (U. S. Public Health Service, 1943, p. 1018). Total sulfate loads were, for example, 1915 - 2,000 tons/day, 1920 - 3,100 tons/day, 1930, 2,100 tons/day, 1940 - 3,100 tons/day. The minimum loading since 1915 occurred during 1915 and the maximum was about 4,200 tons/day in 1927. The maximum total sulfate load during 1946-1963 was about 4,500 tons/day in 1951 and the minimum load was about 2,650 tons/day in 1962.

It is not presently known if the fluctuations in mine drainage pollution in the Allegheny basin can be explained, but it is clear that the loads since 1915 have fluctuated in the same general range and it would seem reasonable to expect this to continue in the foreseeable future unless abatement measures are taken.

Clark (1965) showed evidence that the Monongahela River experienced large increases in acidity during the period 1920-1934 then decreased very gradually in acidity up to 1957. Clark's data indicate very little change from 1944 to 1957. Clark's data are confirmed by data in Figure 41, which show that acidity and sulfate loads in the Monongahela River at Charleroi experienced little permanent change during the period 1945-1958.

Clark (1965) also showed that acidity concentrations in the Monongahela River apparently responded somewhat to rates of mining in the river basin. Coal production in the entire Monongahela basin was about 100 million tons in 1945 and about 65 million tons in 1958 and 1965. Projected production for 1980 is about 90 million tons (computed from Little, 1964).

On the basis of past and present water quality and past, present, and projected mining rates, it would be expected that mine drainage pollution in the Monongahela basin will not be greatly different in 1980 than today, unless corrective measures are taken.

Data available for the Big Sandy River basin (Fig. 52) show that little change in the loads of sulfate originating from mine drainage pollution occurred between 1957 and 1963. Coal production in 1980 is expected to be about 85 million tons as compared to 65 million tons in 1965 (computed from Little, 1964). Mine drainage pollution would not be expected to be substantially different in 1980 than it is today based on past water quality and projected increases in coal mining rates. A maximum increase of about 20 percent in pollution loads would be projected if loads responded directly to mining activity.

The total mine drainage pollution load in the Hocking River as indicated by sulfate loads (Fig. 46) is not great in comparison to some other drainage basins, but it is large in view of the amount of coal extracted (1.6 million tons in 1965). Data in Figure 46 indicate an increase in sulfate loads of about 50 percent between 1955 and 1965. Coal production of about 10 million tons per year is projected for 1980 (computed from Little, 1964). Such a large increase in mining activity could lead to substantially increased mine drainage pollution loads in the Hocking basin, if corrective measures are not applied.

The previous discussion of seven of the sub-areas included in this report indicates that while fluctuations have occurred in mine drainage pollution loads, no substantial permanent increases or decreases in loads appear to have occurred in recent years. An exception to this generalization may be the Hocking basin, where there is a possible trend toward increasing pollution loads. On the basis of the data from the seven sub-areas, which discharge about two-thirds of the mine drainage acidity formed in Appalachia, it is believed that the total quantity of mine drainage pollutants discharged to streams in Appalachia will remain in the same order of magnitude in 1980 as today unless corrective measures are applied.

Although the quantity of pollutants discharged to streams may remain in the same order of magnitude between now and 1980, it is expected that the mine drainage pollution problem will become more severe in terms of the number of inactive mines contributing pollution. In addition, unless controls are exercised, previously unpolluted streams will be degraded as mining advances into new areas.

REFERENCES

American Public Health Association, American Water Works Association, and Water Pollution Control Federation, 1965, Standard Methods for the Examination of Water and Wastewater - 12th edition: American Public Health Association, 769 p.

Arndt, H. H., Averitt, Paul, Dowd James, Frendzel, D. J., and Gallo P. A., 1968, Coal, in Mineral Resources of the Appalachian Region, U. S. Geological Survey Prof. Paper 580, p 120.

Brant, R. A., and DeLong, R. M., 1960, Coal Resources of Ohio: Ohio Department of Natural Resources Geological Survey Bull. 58, 245 p.

Charmbury, H. B., Maneval, D. R., and Girard, Lucien, 1967, Operation Yellowboy - Design and Economics of a Lime Neutralization Mine Drainage Treatment Plant, paper presented at the 96th Annual Meeting of the AIME, Los Angeles, February, 1967.

Clark, C. S., 1965, Some Factors Involved in the Oxidation of Coal Mine Pyrite and Water Quality Trends in the Monongahela River Basin: in Papers Presented Before the Symposium on Acid Mine Drainage Research, Mellon Institute, Pittsburgh, Pennsylvania, May 20-21, 1965.

Culbertson, W. C., 1964, Geology and Coal Resources of the Coal Bearing Rocks of Alabama: U. S. Geological Survey Bull. 1182-B, p B1-B79.

Eavenson, H. N., 1942, The First Century and a Quarter of American Coal Industry: Waverly Press, Baltimore.

Federal Water Pollution Control Administration, 1968, FWPCA Interim Methods for Chemical Analysis of Surface Waters - September 1968, Federal Water Pollution Control Administration, Division of Research, Analytical Quality Control Branch, 1014 Broadway, Cincinnati, Ohio 45202.

Haliburton Company, 1967, Feasibility Study on the Application of Various Grouting Agents, Techniques and Methods to the Abatement of Mine Drainage Pollution: Part I Exploration of Mine Sites and Feasibility Study on Techniques of Materials Application: 226 p., August.

Hodge, W., 1938, The Effect of Coal Mine Drainage on West Virginia Rivers and Water Supplies: West Virginia Engineering Experiment Station Research Bull. No. 18.

REFERENCES (cont'd)

Huddle, J. W., and others, 1963, Coal Reserves of Eastern Kentucky: U. S. Geological Survey Bull. 1120, 247 p.

Hyland, John, 1966, Handbook of Pollution Control Costs in Mine Drainage Management: U. S. Department of the Interior, Federal Water Pollution Control Administration, December, 54 p.

Joseph, J. M., 1953. Microbiological study of acid mine waters. Preliminary report: Ohio Jour. Sci., V-53, No. 2, p. 123-127.

Lackey, J. B., 1938. The flora and fauna of surface waters polluted by acid mine drainage: Pub. Health Rep., V-53, No. 34, p. 1499-1507.

Lackey, J. B., 1939. Aquatic life in waters polluted by acid mine waste: Pub. Health Rep., V-54, No. 18, p.740-746.

Little, A. D., 1964, Projective Economic Study of the Ohio River Basin: Vol. 3, Appendix B, Ohio River Basin Comprehensive Survey, U. S. Army, Corps of Engineers, Cincinnati, Ohio

Lorenz, W. C., 1966, Mineral Industry Water Requirements and Waste Water in the Susquehanna River Basin: U. S. Bureau of Mines, 116 p.

Luther, E. T., 1959, The Coal Reserves of Tennessee: Tennessee Department of Conservation and Commerce, Division of Geology Bull. 63, 294 p.

Maryland Department of Water Resources, 1965, Western Maryland Mine Drainage Survey 1962-1965, Vols. I-III: Maryland Department of Water Resources, Water Quality Division.

McClellan, H. A., and Zoellner, D. R., 1966, Final Report of Biological Investigations in Jefferson and Walker Counties, Alabama: Unpublished report Federal Water Pollution Control Administration, Atlanta, Georgia.

McKee, J. E. and Wolf, H. W., 1963, Water Quality Criteria: California State Water Quality Control Board, Publication No. 3-A, 548 p.

Ohio Department of Industrial Relations, 1965, Annual Report, Division of Mines

Parsons, J. D., 1957. Literature pertaining to formation of acid-mine wastes and their effects on the chemistry and fauna of streams: Trans. Ill. State Acad. Sci., V. 50, p. 49-59.

REFERENCES (cont'd)

Pennsylvania Department of Health, 1965, Report on Pollution of Slippery Rock Creek: Division of Sanitary Engineering, Report No. 8, 76 p.

Pennsylvania Sanitary Water Board, 1967, Proposed Water Quality Standards for Pennsylvania's Interstate Streams.

Rainwater, F. H., and Thatcher, L. L., 1960, Methods for Collection and Analysis of Water Samples: U. S. Geological Survey Water Supply Paper 1454, 301 p.

Reese, J. F., and Sisler, J. D., 1928, Bituminous Coal Fields in Pennsylvania: Penn. Topographic and Geologic Survey Bull., 153 p.

Shapiro, M. A., Andelman, J. B., and Morgan, P. V., 1966, Intensive Study of the Water at Critical Points on the Monongahela, Allegheny, and Ohio Rivers in the Pittsburgh, Pennsylvania area: University of Pittsburgh, 126 p.

Sidio, A. D., and Mackenthun, K. M., 1963, Report on the Pollution of the Interstate Waters of the Monongahela River System: U. S. Department of Health, Education, and Welfare, Public Health Service, unpublished report.

U. S. Department of Agriculture, Soil Conservation Service, 1966, Investigation Report on Luxapallila Creek Watershed in Alabama: unpublished report, U. S. Department of Agriculture.

U. S. Department of Health, Education and Welfare, Public Health Service, 1962 Drinking Water Standards, 61 p.

U. S. Department of Health, Education and Welfare, 1963, Conference in the Matter of Pollution of the Interstate Waters of the Monongahela River and its Tributaries, Vols. 1, 2 and 3, 662 p.

U. S. Department of the Interior, Fish and Wildlife Service - Bureau of Sport Fisheries and Wildlife, Resource Publication 27, 1965, National Survey of Hunting and Fishing.

U. S. Department of the Interior, Fish and Wildlife Service, 1967, Ohio River Basin Comprehensive Survey, Vol. 8, Appendix G: U. S. Army Corps of Engineers, Cincinnati, Ohio

U. S. Department of the Interior, 1967, Interim Report of the National Technical Advisory Committee on Water Quality Criteria to the Federal Water Pollution Control Administration, June 30.

REFERENCES (cont'd)

U. S. Department of the Interior, 1966, Study of Strip and Surface Mining in Appalachia, an Interim Report by the Secretary of the Interior to the Appalachian Regional Commission, 78 p.

U. S. Geological Survey and U. S. Bureau of Mines, Mineral Resources of the Appalachian Region, 1968, U. S. Geological Survey Prof. Paper 580, 492 p.

U. S. Public Health Service, Division of Water Supply and Pollution Control, 1962, Acid Mine Drainage - A Report Prepared for the Committee on Public Works House of Representatives 87th Congress, 2nd Session, House Committee Print No. 18, 24 p.

U. S. Public Health Service, 1954, West Fork River Investigation, Benefits to Pollution Abatement and Improved Water Quality by Flow Regulations from Stonewall Jackson Reservoir, West Fork River, near Brownsville, West Virginia: U. S. Department of Health, Education and Welfare, PHS Report.

U. S. Public Health Service, 1943, Ohio River Pollution Control: Report of the U. S. Public Health Service to the 78th Congress, Part II and Supplements to Part II, Supplement C. Acid Mine Drainage, p. 973-1024.

Virginia Department of Labor and Industry, 1965, Annual Report of the Division of Mines.

Wessel, W. F., 1966, Mineral Resources in the Susquehanna River Basin: U. S. Bureau of Mines, 85 p.

Wessel, W. F., Frendzel, D. J., and Cazell, G. F., 1964, Mineral Industry, Economics in the Susquehanna River Basin: U. S. Bureau of Mines, 90 p.